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OF THE

GEOLOGICAL SURVEY OF INDIA.

VOLUME 74, PART 1.

1939.

CONTENTS

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RECENT PUBLICATIONS OF THE GEOLOGICAL SURVEY OF INDIA.

RECORDS.

Vol. LXX, 1936.

Quinquennial Review of Mineral Production of India for 1929-1933. Price 6 Rs. 4 As.

Vol. 72, 1937.

Part 1.—General Report for 1936. Note on 'oolite'. Freshwater and Land Fossil Molluscs from near Ghorband, Afghanistan. Provisional statistics of some of the more important Indian Minerals for 1936. Miscellaneous Note; Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1936.

Part 2.—Snout of Gangotri Glacier, Tehri Garhwal. Petroleum Technology in Burma during 1936 with special reference to Protection of Oil and Gas Sands. Cretaceous Volcanic Series of Astor Deosai, Kashmir, and its Intrusions. Permo-Carboniferous Limestone Inliers in Sub-Himalayan Tertiary Zone of Jammu, Kashmir, Himalaya. Shark Tooth from Lower Eocene. Fossil Fish-remains from Karewas of Kashmir. Fossil Fish-remains from Saline Series of North-Western India. Fossil Plants from Po Series of Spiti. Polished and Thin Section Technique in the Laboratory of the Geological Survey of India. Marble and Dolomite of Gundai Tarako, North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1937.

Part 3.—Mineral Production of India during 1936. Microscopical Study of Bawdwin Ores, Burma. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: April to June, 1937.

Part 4.—Geology of Palanpur, Danta and part of Idar States. Himalayan Border compared with Alps. Pleistocene Glaciation in North-Western India, with special reference to Erratics of Punjab. Water-Supply of Isa Khel and Mianwali Tahsils of Mianwali District, Punjab. Fossil Anthropoids of India: a list of fossil material hitherto discovered from Tertiary deposits of India. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma; July to September, 1937.

Vol. 73, 1938.

Part 1.—General Report for 1937. The Hindu Kush Earthquake of the 14th November, 1937. On Khoharite, a New Garnet, and on the Nomenclature of Garnets. Provisional Statistics of some of the more important Indian Minerals for 1937. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: October to December, 1937.

Part 2.—The Geology of Gujarat and Southern Rajputana. Tin-Tungsten Mineralisation at Mawchi, Karenni States, Burma. Two Fossil Dicotyledonous Woods from the Garo Hills, Assam. On some Fossil Fish-scales from the Inter trappean Beds at Deothan and Kheri Central Provinces. Miscellaneous Notes: Tirodite, a manganese amphibole from Tirodi, Central Provinces. Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma; January to March 1938. Bismuthinite and bismutosphaerite from Manbhum. Apatite and allanite in barytes from Manbhum.

Part 3.—The Mineral Production of India and Burma during 1937. The Western Margin of the Eastern Ghats in Southern Jeypore. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India and Burma: April to June 1938.

Part 4.—Are the Equidae reliable for the correlation of the Siwaliks? Contributions to the Geology of Yunnan in Western China: 10.—The distribution, age and relationships of the Red Beds. A Seismological Study of the Baluchistan (Quetta) earthquake of May 31, 1935. Earthquake shocks at Paliyad in Kathiawar.

MEMOIRS.

Vol. LXVII, Pt. 1, 1936 (*price* 7 Rs. 12 As.): The Geology of South-eastern Mewar, Rajputana. Pt. 2, 1936 (*price* 4 Rs. 12 As.): The Tertiary Igneous Rocks of the Pakokku District and the Salingyi Township of the Lower Chindwin District, Burma, with special reference to the Determination of the Felspars by the Fedoroff Method.

Vol. LXIX, Pt. 1, 1937 (*price* 9 Rs. 8 As.): The Mineral Deposits of Eastern Singhbhum and Surrounding Areas.

Vol. LXX. An Attempt at the Correlation of the Ancient Schistose Formations of Peninsular India: Part 1, 1936 (*price* 1 Re. 4 As.) Part 2, No. 1, 1936 (*price* 2 Rs. 4 As.).

Vol. 71, 1937 (*price* 6 Rs. 12 As.): The Geology of Gangpur State, Eastern States.

Vol. 72, Pt. 1, 1938 (*price* 5 Rs. 12 As.): The Geology of Parts of the Minbu, Myingyan, Pakokku, and Lower Chindwin Districts, Burma. Pt. 2, *price* 6 Rs. 2 As. The Geology of Parts of the Minbu and Thayetmyo Districts, Burma.

POST CARD.

To

The Director,

Geological Survey of India,

27, Chowringhee Road,

Calcutta.

NOTICE.

Records, Vol. 73, Part 4, is in the press and will be issued later.

To

The Director,

Geological Survey of India,

27, Chowringhee Road,

Calcutta.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA

Part 1.] **1939** **[March**

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1938. BY A. M. HERON, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.R.A.S.B., F.N.I., *Director, Geological Survey of India.*

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DISPOSITION LIST.

During the period under report the officers of the Department were employed as follows :—

Superintending Geologists.

DR. C. S. FOX . . Returned from the field in Assam on 9th March 1938. Remained in charge of the North-eastern Circle and continued the geological survey of the Garo Hills district, Assam. Left for

field work in the Khasi and Jaintia Hills, Assam, on 7th December 1938, and returned to headquarters on 23rd December, 1938.

MR. E. L. G. CLEGG . On foreign service in the Burma Geological Department. Carried out geological traverses in the first defile of the Irrawaddy, the Jade Mines district, Lai Sai State, the Uyu River, Northern Burma. Left for the field on 3rd December, 1937 and returned to Rangoon on 5th April, 1938. Carried out the duties of the Resident Geologist, Yenangyaung, in addition to his own duties, for 6½ months from 17th May, 1938, Mr. Bradshaw having gone on combined leave.

DR. H. CROOKSHANK . Continued in charge of the Southern Circle, mapping in the Bastar State. Returned to headquarters on the 5th May, 1938. Visited Paliyad, Kathiawar, from the 26th July to the 5th August, 1938 to investigate the cause of earthquake shocks there. Granted combined leave out of India for 10 months from 1st December, 1938.

DR. A. L. COULSON . Geological survey in the North-West Frontier Province and in charge of the North-Western Circle. Left for the field on 10th January, 1938. Investigated the water-supply problems of Quetta-Pishin district, Baluchistan, Mianwali district, Punjab, and grid sub-stations in the N.-W. F. P. Examined building sites at Dalhousie. Proceeded on leave out of India from the field on the 14th April, 1938, and returned to duty on the 7th November, 1938. On return from leave left for field work in the North-West Frontier Province on 5th December, 1938.

Geologists.

MR. E. J. BRADSHAW — On foreign service in the Burma Geological Department. Continued as Resident Government Geologist, Yenangyaung, and official member of the Advisory Board of the Yenangyaung and Singu Oilfields. Granted combined leave out of Burma for 6½ months from the 17th May, 1938. Returned from leave on the 3rd December, 1938.

MR. D. N. WADIA — Officiated as Superintending Geologist *vice* Dr. A. L. Coulson on leave and held charge of the North-Western Circle from the 14th April to the 22nd October, 1938. Left for the field on the 5th March, 1938 and continued the mapping of the Tertiaries of the Jammu hills. Returned to headquarters on 8th September 1938. Proceeded on leave for 6 months on the 23rd October, 1938, preparatory to retirement.

DR. J. A. DUNN . — Continued as Petrologist at headquarters till the 31st May, 1938. Proceeded on combined leave out of India for 4 months 24 days from the 4th May, 1938. Returned to headquarters on 10th October, 1938. Left for the field on the 12th November, 1938, for work on the mica belt in Bihar and in Gangpur, Keonjhar and Bonai States, Eastern States Agency. Officiated as Superintending Geologist *vice* Dr. H. Crookshank on leave and placed in charge of the Southern Circle from the 1st December, 1938.

MR. E. R. GEE — Returned from combined leave out of India on the 15th December, 1938. Left to investigate the water supply of Quetta and for field work in the Salt Range, Punjab, on 3rd November, 1938.

MR. W. D. WEST . . Continued as Assistant Director till the 21st July, 1938. Proceeded on combined leave out of India for 11 months and study leave for 4 months from the 22nd July, 1938.

DR. M. S. KRISHNAN . Returned from the field on 2nd May, 1938. Appointed Assistant Director on 22nd July, 1938.

MR. J. B. AUDEN . . Returned from leave out of India on the 15th October, 1938, and remained at headquarters until the end of the year.

MR. V. P. SONDHI . Returned from leave out of India on the 6th December, 1938. Left for the field in the Khasi and Jaintia Hills, Assam, on the 10th December, 1938.

DR. P. K. GHOSH . . Returned to headquarters from the Bastar State on the 27th April, 1938. Appointed Petrologist from the 4th May, 1938.

DR. M. R. SAHNI . . Remained at headquarters as Palæontologist.

MR. A. M. N. GHOSH . Returned from the field in the Khasi and Jaintia Hills, Assam, on the 15th June, 1938. Left for the field to continue his previous work in Assam on the 7th December, 1938.

DR. B. C. ROY . . Left for the field in the Eastern States Agency on the 14th January, 1938. Returned to headquarters on the 24th April, 1938. Granted earned leave for 13 days from the 25th April, 1938. Left for the field on the 3rd December, 1938, for work in the Sambalpur district, orissa and in the Bamra State, Eastern States Agency.

Chemist.

DR. R. K. DUTTA ROY Remained at headquarters. Confirmed in his appointment on the 5th November, 1938.

Assistant Geologists.

MR. D. BHATTACHARJI — Returned from the field on the 18th May, 1938. On leave on average pay from the 17th June to the 31st August, 1938 and again from the 14th November to the 23rd December, 1938.

MR. B. C. GUPTA — Returned from the field on the 30th April, 1938. Left for the field on the 10th December, 1938, to continue work in the Drug and Chanda districts, Central Provinces, and in the Nandgaon State, Eastern States Agency.

MR. H. M. LAHIRI — Returned from the field on the 24th April, 1938. On leave on average pay from the 2nd May to the 1st July, 1938. Left for the field in the Gurdaspur, Hoshiarpur, Kangra and Ambala districts, Punjab, on the 7th December, 1938.

DR. L. A. N. IYER — Carried out economic investigations in the Ratnagiri district and Savantvadi States, Bombay. Returned to headquarters on the 7th March, 1938. Left headquarters on the 14th March, 1938 for the geological survey of the mica belt in the Hazaribagh district and returned to headquarters on the 20th April, 1938. Left for work in the mica-mining areas of Gaya, Monghyr and Hazaribagh districts, Bihar, on the 12th November, 1938.

MR. P. N. MUKERJEE — Left for the field in Assam on the 7th February, 1938. Returned to headquarters on the 7th May, 1938. Left for the field on the 20th December, 1938, for work in the Khasi and Jaintia Hills district, Assam.

DR. A. K. DEY — Continued on foreign service in Jashpur State, Eastern States Agency. Returned from the field to Calcutta on the 31st May,

	1938. Left for field work in Jashpur State on the 10th December, 1938.
MR. V. R. R. R. KHEDKER	Returned to headquarters from the field on the 5th May, 1938. Left for the field on the 5th December, 1938, to carry on geological mapping in the Khasi and Jaintia Hills district, Assam.
MR. P. C. DAS HAZRA .	Returned from the field on the 4th September, 1938. Left for the field on the 9th December, 1938, to continue the geological mapping of the Gurdaspur district, Punjab, and Kathua district of Kashmir and Jammu State.

Artist.

MR. S. ROY .	Remained at headquarters. Granted earned leave for 2 months and 1 day from the 29th July, 1938.

Curator.

MR. P. C. ROY	At headquarters.

Field Collectors.

MR. N. K. N. AIYENGAR	At headquarters.
MR. A. B. DUTT . .	Officiated as Assistant Geologist *vice* Dr. A. K. Dey on foreign service and continued geological survey work in Burma. On foreign service under the Government of Burma until his return from the field on the 3rd May, 1938. Left for field work in Burma on the 3rd December, 1938.

Assistant Chemist.

MAHADEO RAM	On leave on average pay from the 19th April, 1938 to the 24th May, 1938. At headquarters.

Museum Assistants.

D. GUPTA . . .	At headquarters.
M. S. VENKATRAM .	At headquarters. Continued to officiate as Field Collector *vice* Mr. A. B. Dutt.
V. BHASKARA RAO .	Resigned from service with effect from the 16th February, 1938.
B. G. DESHPANDE .	Confirmed on 1st May, 1938. At headquarters. On leave from the 15th December, 1938, to the 23rd December, 1938.

The cadre of the Department, at the end of the year, consisted of 4 Superintending Geologists, 12 Geologists and 1 Chemist.

ADMINISTRATIVE CHANGES.

Promotions and appointments.

Mr. D. N. Wadia officiated as Superintending Geologist from the 14th April, 1938 to the 22nd October, 1938, *vice* Dr. A. L. Coulson on leave.

Dr. J. A. Dunn officiated as Superintending Geologist from the 1st December, 1938 *vice* Dr. H. Crookshank on leave.

Dr. M. S. Krishnan was appointed Assistant Director from the 22nd July, 1938.

Dr. P. K. Ghosh was appointed Petrologist from the 4th May, 1938.

Dr. R. K. Dutta Roy was confirmed in his appointment as Chemist from the 5th November, 1938.

Mr. V. R. R. R. Khedker was confirmed in his appointment as Assistant Geologist from the 1st March, 1938.

Mr. P. C. Das Hazra was confirmed in his appointment as Assistant Geologist from the 1st March, 1938.

Mr. A. B. Dutt continued to officiate as Assistant Geologist during the year, *vice* Dr. A. K. Dey on foreign service in Jashpur State.

Leave.

Dr. H. Crookshank was granted leave on average pay for 4 months combined with leave on half average pay for 6 months from the 1st December, 1938.

Dr. A. L. Coulson was granted combined leave out of India from the 14th April, 1938 to the 3rd November, 1938.

Mr. E. J. Bradshaw was granted leave on average pay for 4 months combined with leave on half average pay for 2½ months from the 17th May, 1938.

Mr. D. N. Wadia was granted leave on average pay for 6 months from the 23rd October, 1938, with permission to retire from service on the conclusion of his leave.

Dr. J. A. Dunn was granted combined leave out of India from the 4th May, 1938 to the 27th September, 1938, with permission to affix the Puja holidays.

Mr. W. D. West was granted leave out of India on average pay for 8 months combined with leave on half average pay for 3 months and study leave for 4 months from the 22nd July, 1938.

Dr. B. C. Roy was granted earned leave for 13 days from the 25th April, 1938.

Mr. D. Bhattacharji was granted leave on average pay from the 17th June, 1938 to the 31st August, 1938 and again for 1 month and 10 days from the 14th November, 1938, with permission to affix the Christmas and New Year's Day holidays.

Mr. H. M. Lahiri was granted leave on average pay for 2 months from the 2nd May, 1938 to the 1st July, 1938.

OBITUARY.

Thomas Henry Digges La Touche died on the 30th March, 1938. Mr. La Touche joined the Geological Survey of India on the 29th November, 1881, and retired from service on the 30th October, 1910. An obituary notice has been published in the *Records, Geological Survey of India,* Volume 72, Part 4.

HONOURS AND AWARDS.

The title of M. B. E. was conferred on Mr. V. P. Sondhi, Geologist in this Department.

The Government of India prize of Rs. 500 awarded annually by the Council of the Mining, Geological and Metallurgical Institute of India for 'the best paper by a member read before the Institute and published in the *Transactions* each year' was awarded for the year ending 31st October, 1938 to Mr. J. Thomas for his paper entitled 'Methods of Stowing for Indian Mines.'

LECTURESHIP.

Dr. J. A. Dunn acted as part-time Professor of Geology at the Presidency College, Calcutta till the 3rd May, 1938, and thereafter Dr. P. K. Ghosh.

POPULAR LECTURES.

The following popular lectures were delivered by officers of the Department during the year :—

(1) " Earthquakes in India " by Mr. W. D. West, at the Bengal Engineering College, Sibpur.

(2) " A Geologist in Russia " by Dr. C. S. Fox, at a Rotary Club Luncheon held at the Great Eastern Hotel, Calcutta.

EXHIBITIONS.

The following maps were demonstrated at the scientific exhibition organised in connection with the Annual Meeting of the National Academy of Sciences, India, held at Allahabad on the 5th March, 1938 :—

1. Geological foundations for the Chief Soil-groups of India.
2. The principal limestone outcrops influencing the Soils of India.
3. Earthquake Map of India.
4. Mineral Map of South-east Chota Nagpur. Scale 1″=4 miles.
5. Map showing the Chief Mineral Deposits of Bihar and Orissa.
6. Map showing the Chief Mineral Deposits of the Central Provinces.
7. Geological Map of the Jharia Coalfield, Scale 1″=1 mile.
8. Geological Map of the Raniganj Coalfield (Eastern Area) Scale 1″=1 mile.
9. Geological Map of the Raniganj Coalfield (Western Area), Scale 1″=1 mile.
10. Geological Map of the Tavoy district, Scale 1″=4 miles.
11. Geological Map of Bihar and Orissa, Scale 1″=16 miles.

PUBLICATIONS.

The following were published during the year under report :—

1. Records, Vol. 72, Part 4.
2. Records, Vol. 73, Part 1.

3. Records, Vol. 73, Part 2.
4. Records, Vol. 73, Part 3.
5. Memoirs, Vol. 72, Part 1.
6. Memoirs, Vol. 72, Part 2.
7. Palæontologia Indica, New Series, Vol. XXV, Memoir No. 1.
8. Geographical Index to Memoirs (I-LIV), Records (I-LXV), and General Reports, of the Director for the years 1897 to 1903.

LIBRARY.

The additions to the Library amounted to 3,108 volumes, of which 1,105 were acquired by purchase and 2,003 by presentation and exchange.

DRAWING OFFICE.

Mr. S. Roy was in charge of the Drawing Office throughout the year, except for a period of one month and 28 days, from the 29th July to the 27th September, when he was on leave on average pay.

Publications.

During the year 156 half tone and line blocks, one coloured line map and 5 litho stones were prepared for plates for the *Records*, *Memoirs* and *Palæontologia Indica*, and 74 plates were printed off; 142 drawings, maps and diagrams and 44 line blocks for text figures were also made.

The number of geologically coloured originals received from officers totalled 83, while 1,601 topographical sheets were received from the Director, Map Publication, Survey of India, and 472 were issued for departmental use.

Photographic section.

The photographic section was fully occupied with copying, developing, enlarging and printing work for publications and reports. The number of negatives received into stock (registered) totalled 269, while 1,068 photographic prints were made. In addition, 83 lantern slides were made.

MUSEUM AND LABORATORY.

Staff.

Dr. J. A. Dunn continued to act as Petrologist until his departure on leave on the 3rd of May, Dr. P. K. Ghosh succeeded him as Petrologist from the 4th of May until the end of the year. Mr. P. C. Roy continued as Curator of the Geological Museum and Laboratory.

Messrs. D. Gupta and B. G. Deshpande continued as Museum Assistants throughout the year. Mr. V. Bhaskara Rao resigned his post as Museum Assistant on the 16th of February 1938. The services of the temporary Museum Assistant, Mr. P. K. Chatterjee, were dispensed with from the 1st of November, 1938, as a measure of retrenchment.

Dr. R. K. Dutta Roy continued as Chemist and Babu Mahadeo Ram as Assistant Chemist throughout the year.

Determinative work.

The number of specimens determined in the Laboratory was 876, of which 158 were quantitatively analysed or otherwise specially tested in the Chemist's section. The corresponding figures for the previous year were 611 and 82 respectively. The numbers of specimens determined this year are the highest on record, the average for the past ten years being 662 and 84 respectively. Much of the analytical work was of a specialised character. The chemical work included analyses of rocks, coal, iron-ore, manganese-ore, chromite, bauxite, antimony-ore, wolfram, lead-ore, limestone, sands, fossil coprolites and a good many gold and silver assays. Special tests were also made for several rare earths. The Laboratory worked at its full capacity, and in some instances overtime. In consequence of the large influx of samples forwarded by officers of this department, in addition to those sent in by the public, it is extremely difficult to cope with the work with one chemist and one assistant only. In fact a great deal of discriminatory selection and restriction has to be done with the samples submitted by officers of the department, so as to keep them within the ability of the Laboratory staff to cope with the work. Much interest is now-a-days evinced by the public and the various Provincial Governments in economic minerals, but the inadequate staff of the laboratory makes it difficult to render them fully effective help in this direction. The rock-section cutting machinery and the automatic polishing machine installed last year continued to work satisfactorily and were of considerable help in coping with the increased volume of work. An electrometer for determining the radio-activity of rocks, minerals and mineral water has been set up and some determinations have been made.

During the year the reconditioning of the show-cases in the Museum was continued. The work of re-arrangement of the

rock collections undertaken last year has been brought to completion. The rock collections comprise the specimens collected by the officers of the Geological Survey of India and are, along with the economic minerals, now arranged according to the Provinces in which they occur. It is hoped that visitors will be more interested than before in these exhibits as these will show them at a glance the types of rocks and economic minerals which occur in their respective Provinces. The re-arrangement of the mineral collection has now been taken in hand.

Reorganisation of the Museum.

Presentations of collections of rocks and minerals were made to the following institutions during the year :—

Donations to Institutions, etc.

1. David Hare Training College, Calcutta.
2. St. Joseph's College, Calcutta.
3. St. Thomas' School, Calcutta.
4. Government High School, Banda, U. P.
5. St. Xavier's College, Calcutta.
6. Ranchi Zilla School.
7. Presidency College, Calcutta.
8. Mandalay Agricultural College, Burma.
9. Moga Training School, Moga, Punjab.
10. Lahore College for Women, Lahore.
11. St. Paul's School. Jalapahar, Darjeeling.
12. Presidency College, Madras.
13. Kala Bhavan Technical Institute, Baroda.
14. Union Christian College, Berhampur, Bengal.
15. Department of Chemistry. Annamalai University.
16. Panchgani H. E. School, Bombay.
17. A. B. M. Girls' H. E. School, Kemmendine, Burma.
18. Benares Hindu University.
19. Government Metal Working School, Aligarh.
20. Municipal Central Girls' School, Ajmer.
21. Hindu High School, Raipur, C. P.
22. Gordon College, Rawalpindi.

Twenty-two collections as compared with an average of nine during the past ten years.

In addition, the following special presentations were made :—

1. Charnockite specimens to Prof. F. K. Morris, Massachusetts Institute of Technology, Cambridge, U. S. A.

2. Specimens of gypsum, bauxite, pyrite and magnetite to Pundit Deb Prasad G. P. of Palpa, Gorakhpur district, U. P.
3. Specimens of the charnockite series to Dr. R. Campbell, Department of Geology, University of Edinburgh.
4. Charnockite specimens to the Professor of Geology, Aberdeen University.
5. Shell limestone to Mr. S. R. Narayan Rao, Intermediate College, Mysore.
6. Manganiferous spessartite-rocks to Mr. H. Collins of the Imperial College of Science and Technology, London.
7. A specimen of sillimanite to Mr. Walden A. Smith, Ilwaco, Washington, U. S. A.
8. Coulsonite, hollandite, sitaparite and 'vredenburgite' to Mr. F. C. Partridge, Pretoria, South Africa.
9. Diamondiferous gravels to the British Museum, London.
10. A collection of saltpetre to Prof. H. Seifert, Mineralogisch-Petrographisches Institut und Museum der Universität, Berlin.
11. Quartz crystal to Dr. J. P. Bose, School of Tropical Medicine, Calcutta.
12. Bauxite to Mr. B. L. Vaid, Vakil, Rajaldisar, Bikaner State.
13. Zeolites, chromite, sitaparite, fermorite and 'vredenburgite' to the Mineral Department, Ward's Natural Science Establishment, Rochester, New York.
14. Hollandite and fermorite to the Director, Geological Survey, Union of South Africa.
15. A collection of Indian manganese-ores and zeolites to Mons. F. W. Cassirer, Prague, Czechoslovakia.
16. Asbestos and bauxite to Miss Stewart, Calcutta Boys' School.
17. Specimens of asbestos to Mr. W. J. McKeon of Technical Data Section, Johns-Manville Sales Corporation, New York.
18. Micaceous hæmatite to the Mineral Adviser to the High Commissioner for India, London.
19. Ilmenite and monazite sand to the Ceylon Trade Commissioner, Bombay.
20. Indian manganese minerals, cassiterite, wolfram and a polished section of coulsonite to the Australian Museum, Sydney.

21. Khondalite and charnockite series of rocks to Mr. H. C. Richards, Department of Geology, University of Queensland, Australia.
22. Juddite, zeolites and one polished section of coulsonite to the Smithsonian Institution, Washington.
23. Magnetite, ilmenite, hæmatite and bauxite to the Agricultural Research Chemist, University of Dacca.
24. Graphite to Prof. Rajnath, Benares Hindu University.
25. A collection of economic minerals to Mr. Church, Iron and Steel Works, Broken Hill Proprietory Ltd., Newcastle, New South Wales, Australia.
26. A collection of ore minerals to Mons. J. Orcel, Professor of Mineralogy, Museum National d'Histoire Naturelle, Paris.
27. Fifty pounds of kyanite to the Mineral Research Laboratory, University of the Witwatersrand, Johannesburg, South Africa.
28. A collection of Indian economic minerals to the Rev. Austere, Institut St. Edward Merxem, Antwerp, Belgium.
29. A collection of economic minerals to the Watson Museum, Rajkot.
30. A collection of rocks and minerals to the British Museum, London.
31. A collection of twelve Indian meteorites to the Kyancutta Museum, Australia.
32. Three Indian meteorites—Perpeti, Patwar and Lua, to Mons. Cassirer, Prague.

Thirty-two presentations as compared with an average of ten for the last ten years.

Additions to the collections.

The large collections of rocks and minerals made by the officers of the Department have, as usual, been incorporated in the Departmental collection; several specimens have also been received through exchange. Among the additions, mention may be made of the following:—

1. A large collection of minerals from the Mawchi mine, Karenni, Burma, from Mr. G. V. Hobson.
2. Quartz crystal from Orchha State, from Mr. K. L. Bhola.
3. A large collection of minerals from Jodhpur State, from Mr. K. L. Bhola,

4. A large collection of minerals from Prof. Schumacher of the Freiberg Mining Academy, Germany.
5. Six ore-minerals from Mons. F. W. Cassirer, Prague.
6. Maghematite and cubanite from the Geological Survey of South Africa.
7. A large collection of minerals from the British Museum, London.
8. Seven minerals from Ward's Natural Science Establishment, Rochester, N. Y.
9. Zinkenite from the Political Agent, Chitral.
10. Safflorite, skutterudite and smaltite from Mons. J. Orcel, Prof. of Mineralogy, Museum National d'Histoire Naturelle, Paris.
11. White clay with (?) diatoms and kankar from the Chief Commissioner, Andaman and Nicobar Islands.
12. Diatomaceous earth from the American Museum of Natural History, New York.
13. Three specimens of diatomite from the British Museum, London.
14. Fifteen polished sections of ore-minerals from Mr. F. C. Partridge, South African Geological Survey, Pretoria.
15. Manganese minerals from the General Manager, C. P. Manganese Ore Company, Nagpur.
16. Kyanite from the Indian Copper Corporation Ltd.

In connection with a scheme for popularising knowledge relating to the industrial application of the more important of India's economic minerals and rocks, some of the leading industrial organisations of the country were approached for gifts of suitable specimens illustrating the various stages in the utilisation of raw materials, and a generous response was met with from the following :—

1. The Tata Iron and Steel Co., Ltd.:—iron ores, fluxes and other raw materials, finished products and by-products, and photographs.
2. The Indian Copper Corporation Ltd., Ghatsila :—copper ores, finished products and photographs.
3. The Kumardhubi Fireclay and Silica Works Ltd.:—clay, bauxite, etc., and finished products.
4. The Assam Oil Co., Ltd., Digboi :—crude petroleum and its derivatives.

5. The Gwalior Potteries Ltd.:—clay, felspar, etc., and some tiles.
6. The Associated Cement Companies Ltd., Lakheri, Rajputana :—clay, limestone, gypsum, etc., cements, and photographs.
7. Messrs. John Taylor and Sons' Committee, Ooregum, Mysore :—auriferous quartz and gold.

Meteorites.

Specimens have been recovered from two meteoric showers during the year, one from Jodhpur State, which has been registered as the 'Rangala' meteorite, a stone meteorite, and the other from Burma, registered as the 'Mabwe-Khoywa' meteorite, also a stone meteorite.

The first meteorite fell at village Rangala under the Police Station Bagora, Jodhpur State, Rajputana, at about 10 a.m. on the 29th December, 1937. Fifteen pieces have kindly been sent by the Chief Minister of Jodhpur State. The total weights recovered amounted to about 3,200 grammes. A paper on this fall has been written by Dr. J. A. Dunn and will be published in the *Records*.

The second fell at Mabwe-Khoywa (? Kyetbogale) village in the Karenni State of Kyetbogyi, 120 miles east of Toungoo, at about 10-40 p.m. on the 17th September 1937.

The phenomenon of this Burmese fall was reported in the "Statesman" of the 21st September 1937 by a Rangoon correspondent who described it as follows :—

> "A meteor was seen in the sky on Friday night between 10-40 and 11 p.m. at various places in Burma. Those seeing the meteor in Rangoon describe the phenomenon as a big ball of fire, low in the sky, with tongues of flames and with a tail of variegated lights, which travelled slowly across the sky and was visible for about 20 seconds. It finally broke up, followed by a rumbling noise and earth-tremors, the latter being strongly felt by the residents of the Toungoo, Yamethin and Mawchi mines."

Mr. Thomson Durmay of Toungoo, who possessed two fragments of this meteorite, generously presented the Department with one piece which, together with another small fragment recovered by the Township Officer, Thandaung, Toungoo district, and kindly forwarded by the Deputy Commissioner of Toungoo, weighed 706 grammes. It is understood Mr. Durmay has another piece of this meteorite weighing about 21 lbs.

A fragment of the 'Bherai' meteorite, which fell in 1893 in Junagadh State, Kathiawar, and which is unrepresented in our

collection, has been obtained on loan from the Watson Museum, Rajkot, for study. It weighs 14·66 grammes and its counterpart in the British Museum 17·5 grammes.

During the year under review the following meteorites were presented to the Department:—

1. Willow Creek by Mons. Cassirer, Prague.
2. Box Hole by the Kyancutta Museum, Australia.
3. Odessa by the U. S. National Museum.
4. Oakley by the U. S. National Museum.
5. Grant by the U. S. National Museum.
6. Dungannon by the U. S. National Museum.
7. Kyancutta by the Kyancutta Museum.
8. Hoba by the Kyancutta Museum.
9. Plain View by the British Museum.
10. Cold Water by Mons. Cassirer, Prague.
11. Woodward County by the U. S. National Museum.
12. Kesen by the U. S. National Museum.
13. Travis County by the U. S. National Museum.
14. Gretna by the U. S. National Museum.
15. Kelly by the U. S. National Museum.
16. Paragould by the U. S. National Museum.
17. Karoonda by the Kyancutta Museum.

PALÆONTOLOGY.

Dr. M. R. Sahni continued to act as Palæontologist throughout the year. Mr. N. K. N. Aiyengar, Field Collector, assisted the Palæontologist during the year in the re-organisation of the Siwalik gallery and in routine work. Mr. M. S. Venkatram, Field Collector, also assisted the Palæontologist in the re-organisation of the Invertebrate Fossil gallery and in the preparation of a catalogue of the reserve fossil collection. Mr. Dasarathi Gupta, Museum Assistant, helped the Palæontologist throughout the year in routine work.

Further progress has been made during the year under review in the re-arrangement of the fossil galleries of the Indian Museum and with the addition of more popular descriptive labels and pictorial restorations of interesting types of mammals. The introduction of descriptive labels in the Indian languages,—Hindi, Bengali and Urdu,—in the Siwalik gallery has been much appreciated by the public.

In the Invertebrate Fossil gallery the work of renovating the show cases and replacing the old labels with new and up-to-date ones has progressed.

During 1938 as many as seven memoirs were received for publication in the *Palæontologia Indica.*

The following papers of palæontological interest are in the press and are expected to be published in 1939 :—

Palæontologia Indica.

(1) L. F. Spath : 'The Cephalopoda of the Neocomian Belemnite Beds of the Salt Range.' Memoir No. 1, Vol. XXV of the New Series.

(2) G. E. Pilgrim : 'The Fossil Bovidæ of India.' Vol. XXVI of the New Series.

(3) M. R. Sahni : 'The Mesozoic Brachiopoda of the Bannu district.' Vol. XXVII of the New Series.

(4) P. N. Mukerjee : 'Fossil Fauna from the Tertiary of the Garo Hills, Assam.' Memoir No. 1, Vol. XXVIII of the New Series.

(5) R. V. Sitholey : 'Jurassic Plants from Afghan Turkistan.' Memoir No. 1, Vol. XXIX of the New Series.

(6) K. Sripada Rao and S. R. Narayana Rao : 'The Fossil Charophyta of the Deccan Intertrappeans near Rajahmundry, (India).' Memoir No. 2, Vol. XXIX of the New Series.

(7) Prof. Baron von Huene : 'The Tetrapod fauna of the Upper Triassic Maleri beds from Maleri, Hyderabad, (Deccan), and Tiki in Central India.'

Records.

(1) D. N. Wadia and N. K. N. Aiyengar : 'Fossil Anthropoids of India' : A list of the fossil material hitherto discovered from the Tertiary deposits of India (Vol. 72, Pt. 4).

(2) K. Ahmad Chowdhury : 'Two Fossil Dicotyledonous Woods from the Garo Hills, Assam.' (Vol. 73, Pt. 2).

(3) S. L. Hora : 'On some Fossil Fish-scales from the Intertrappean beds at Deothan and Kheri, Central Provinces.' (Vol. 73, Pt. 2).

Vertebrates.

The vertebrate fossils collected by Mr. P. C. Das Hazra from the Siwaliks of Jammu were examined and the following provisional identifications have been made by the Palæontologist and Mr. N. K. N. Aiyengar.

Dinotherium indicum, *Tetrabelodon* cf. *angustidens*, *Mastodon* sp., *Stegodon* sp., *Giraffokeryx* cf. *punjabiensis*, *Listriodon sp.*, *Hippohyus* sp., *Conohyus* cf. *sindiensis*, *Conohyus* sp., *Aceratherium* sp., *Rhinoceros* sp., *Chalicotherium* sp., *Bos* sp., *Cervus* sp.

A specimen collected by Pandit Harbans Lall of Baijnath was sent to this department through the Director, Zoological Survey of India and was identified by the Palæontologist as a portion of a *Stegodon* molar.

Specimens of fossil fish collected by Dr. H. Crookshank from the Inter-trappean beds of the Central Provinces were sent to Dr. S. L. Hora for examination. His results are incorporated in a paper recently published. (*Rec. Geol. Surv. Ind.* Vol. 73, Pt. 2.)

Invertebrates.

Dr. M. R. Sahni has been engaged in the investigation of various fossil collections made by officers during the course of their survey work.

A further collection of foraminiferal limestone made by Mr. E. L. G. Clegg from the Myitkyina district has been provisionally examined by Dr. M. R. Sahni and has been found to contain *Orbitolina*, which denotes a Cretaceous age. Some of these limestones probably represent the same horizon as the one which yielded *Orbitolina birmanica* Sahni from the Second Defile of the Irrawaddy and certain localities to the S. S. W. of it.

In addition to a brief memoir on some Mesozoic brachiopods from the Bannu district, Dr. Sahni has nearly completed a memoir dealing with the brachiopods of the Namyau beds (Jurassic) collected during the past few years by himself and others. The genus *Holcothyris* is treated monographically, while several new species belonging to genera not hitherto recorded from Burma are described. Whereas the genus *Holcothyris* suggests an approximately Callovian age for the containing beds, the other species from a different locality seem to represent an older, Bajocian, horizon. It would,

therefore, appear that the Namyaus comprise several Jurassic horizons. Hitherto the only Terebratulid genera recorded from the Namyau beds were *Holcothyris* and a doubtful specimen of *Loboidothyris*. In the collections under report by Dr. Sahni the genus *Loboidothyris* predominates.

Mr. L. R. Cox of the British Museum (Natural History) is engaged in working out a collection of certain Jurassic lamellibranchs from Cutch. He has submitted a memoir dealing with the families Ctenodontidæ, Nuculidæ, Nuculanidæ, Parallelodontidæ, Mytilidæ and Isognomonidæ, for publication in the *Palæontologia Indica*.

A few alveolines sent by Prof. B. Sahni, Botany Department, Lucknow University, and certain freshwater mollusca from the Inter-trappeans sent by Mr. Kazim, Assistant Director of Mines, Hyderabad, were identified by the Palæontologist. The alveolines are referable to *Alveolina javana* and the mollusca mostly to well-known Intertrappean species.

Plants.

Some specimens of fossil plants collected by Dr. C. S. Fox from the Tertiaries of Assam were sent to Prof. B. Sahni for examination. According to him two of the three fruits found with the mammalian bones near Kalaichar bungalow (25°26′: 89°50′) are of special interest. They are referable to the genus *Nipadites*, of which nearly all the previous records are from the Eocene rocks.

Donations.

During the year under review, presentations and loans of fossils or casts were made to the following persons or institutions :—

L. W. Le Roy, Esq., N. V. Petroleum Maatschappij, Sumatra.—A small collection of Tertiary foraminifera from Sind and the Punjab.

St. Xavier's College, Calcutta.—A small collection of vertebrate, invertebrate and plant fossil specimens.

St. Thomas' School, Calcutta.—A small collection of vertebrate, invertebrate and plant fossil specimens.

Intermediate College, University of Mysore, Mysore.—Specimens of *Cardita beaumonti*, a few species of *Assilina* and a specimen of limestone containing *Lepidocyclina* and *Lithothamnion.*

University of Southern California, Los Angeles, California, U. S. A.—A small collection of invertebrate fossils. (By exchange through Prof. A. J. Tieje.)

University of Western Australia, Perth.—A small collection of invertebrate fossils from the Tertiary of Assam and the Jurassic of Cutch.

Kala Bhavan Technical Institute, Baroda.—A small collection of vertebrate, invertebrate and plant fossil specimens.

Pingna H. E. School, Mymensingh.—A specimen of *Perisphinctes* from the Jurassic of Cutch.

Union Christian Training College, Berhampore, Murshidabad.—A small collection of vertebrate, invertebrate and plant fossil specimens.

University of Western Australia, Crowley, W. Australia.—Specimens of *Productus indicus* Waag., *Spirifer marcoui* Waag. *Spiriferina cristata* Schloth. *Spirifer nitiensis* Dien. and *Conularia warthi* Waag.

Agricultural College, Mandalay.—Thirty specimens of invertebrate fossils from Burma.

University of Michigan, Ann Arbor, U. S. A.—About forty species of Permo-Carboniferous fossils from the Salt Range and a small collection of Palæozoic corals from India and Burma.

Wynberg Homes Society, Mussoorie, U. P.—A small collection of vertebrate, invertebrate and plant fossil specimens.

Presidency College, Madras.—A collection of invertebrate and plant fossil specimens.

Benares Hindu University, Benares.—Three specimens of *Rhynchonella plicatiloides*, Stol.

Gordon College, Rawalpindi.—A small collection of vertebrate and invertebrate fossil specimens.

Smithsonian Institution, United States National Museum, Washington, D. C.—A collection of Jurassic and Permo-Carboniferous brachiopods from Cutch, Salt Range and Spiti. In addition to this, casts of *Dictyothyris compressa*, *Aspidothyris kroffti*, *Uncinella indica* and *Enteletes latesinuatus* and a few specimens of *Rhynchonella plicatiloides*. (By exchange.)

The Royal Institute of Science, Department of Zoology, Bombay.—A small collection of vertebrate and invertebrate fossils.

Watson Museum, Rajkot.—A small collection of ammonite fossils from the Jurassic of Cutch.

D. Hooper, Esq., Wellcome Historical Medical Museum, London.—A specimen of a '*salagram*' (Spiti nodule).

British Museum (Natural History), London.—Skulls or horn-cores or parts of upper and lower dentition of *Gazella* sp. cf. *lydekkeri*, *Pachyportax latidens* var. *dhokpathanensis*, *Tragoportax* sp., cf. *aiyengari* or *islami*, *Ruticeros pugio*, *Tragocerus punjabicus*, *Sivaceros* sp., *Dorcadoxa porrecticornis*, *Gazella superba*, *Sivoreas eremita*, *Helicoportax tragelaphoides* and *Strepsiportax* sp. Also a collection of duplicate specimen of Jurassic lamellibranchs from Cutch.

Director, Colombo Museum, Colombo.—Cast of a specimen of the last upper molar of *Palæoloxodon namadicus*.

Australian Museum, Sydney.—Casts of *Martiniopsis inflata* and *M. subpentagonalis*.

During the year the department has received fossil specimens, either by presentation or exchange, from the following:—

Director, City of Liverpool Free Public Museum, Liverpool.—A slab of *Cheirotherium* footprints from the Lower Keuper of Cheshire.

University of Michigan, Ann Arbor, U. S. A.—A collection of Devonian and Cretaceous brachiopods.

University of Western Australia, Crowley, W. Australia.—Specimens of *Chonetes pratti*, *Magadina cretacea* (Ether.), *Trigonosemus acathodes* Ether., *Megas mesembrinus* Ether.

Department of Geology, British Museum (Natural History) London.—Specimens of *Owenites egrediens* Welter, *Hemiprionites timorensis* Spath, *Albanites welteri* Spath and *Palæophyllites steinmanni* Welter from the Upper Eo-trias of Timor.

Smithsonian Institution, United States National Museum, Washington, D. C.—A representative collection of Devonian brachiopods and Lower Triassic ammonites.

Museum of Palæontology, University of California, Berkeley, California.—Several species of *Aucella* from the Jurassic and Cretaceous beds of California.

Prof. Jeannet, Geologisches Institut der Eidg. techn. Hochschule Zurich, Switzerland.—A collection of foraminifera and other fossils representative of the Nummulitic and of the Mesozoic of the Alps and of France.

Director, Kyancutta Museum, South Australia.—Twenty-seven specimens of Archæocyathinæ and one specimen containing sponge spicules from the Lower Cambrian of Ajax Mine, Beltana, South Australia.

University of Southern California, Los Angeles, California, U. S. A.—A small collection of Lower Pleistocene foraminifera from California.

STRATIGRAPHY.

Eocene, Baluchistan.

Dr. A. L. Coulson took advantage of his being in Baluchistan in January 1938, in connection with the water-supply of part of the Quetta-Pishin district, to pay a short visit to the limestones of hill 5916 feet in the Ghazaband pass area in order to inspect certain structures brought to his notice by Mr. E. T. Vachell of the Burmah Oil Company, Ltd. The specimens collected by Dr. Coulson were examined by Mr. H. M. Lahiri, who identified *Discocyclina dispansa*, a Middle Kirthar species. Mr. Eames of the Burmah Oil Company, Ltd., had previously been able to extract *Camerina lævigata* and *C. lamarcki* and had noted forms of *Discocyclina* closely comparable with *D. dispansa* and *D. javana indica* from Mr. Vachell's specimens and considered the fauna to indicate a Middle Kirthar or Upper Kirthar age, the former being perhaps the more likely.

The Middle Kirthar limestone seemed to Dr. Coulson to be resting unconformably, or thrust, upon shales which have been attributed in the past to the Khojak shales.

Age of the Kojak shales, Baluchistan.

While on a visit to Baluchistan in November 1938, in connection with the water-supply of Quetta, Mr. E. R. Gee collaborated with Dr. A. Allison and Mr. A. N. Thomas, of the Burmah Oil Co., Ltd., on a joint investigation into the age of the Kojak shales of the Khojak Pass areas. These strata had originally been regarded by C. L. Griesbach[1] as a flysch facies of the Lower Eocene of Sind but he had found no fossils on which to base this conclusion. On lithological grounds, the Kojak shales were assigned to various stratigraphical horizons by later observers,[2] and finally, on the

[1] *Mem. Geol. Surv. Ind.*, XVIII, Pt. 1, (1881), [Reprint (1933)].

[2] *See* Holland, Sir T. H., Indian Geological Terminology, *Mem. Geol. Surv. Ind.*, XLI, Pt. 1, p. 104, (1926).

evidence of fossils found in the Mekran area, were placed in the Oligocene by E. Vredenburg.[1]

Kojak shales, exactly similar in lithology to those occurring in the Khojak pass (30° 50′ : 66° 35′) were examined by Dr. Allison and Messrs. Gee and Thomas in the hills north of the Surkhab river, 12 to 15 miles east of Pishin (30°35′ : 67°00′) and in two separate sections foraminifera were discovered, also a coral. These fossils were met with at several horizons, in shaly strata and in sandstone and thin limestone bands that are intercalated in the predominantly shale and slaty shale sequence. In the Khojak Pass area, the party was joined by Dr. E. Lehner, also of the Burmah Oil Co., Ltd., and in the sandstones that alternate with shales in the ridge one mile south of Kila Abdullah (30°44′ : 66°40′) at the south-east end of the pass, foraminifera were also discovered. Among these the palaeontologists of the Burmah Oil Co., Ltd., have identified *Lepidocyclina* (*Eulepidina*) and *Camerina Fichteli* which fix the age of the beds as Upper Oligocene (Nari). The passage of the sandstones and shales of Kila Abdullah up into the slaty shales with subordinate sandstones of the higher parts of the Khojak Pass area (the Khwaja Amran range) was examined and appeared to be definitely transitional.

The above-mentioned geologists regard the Kojak shales as representing a flysch facies, and are of the opinion that they have been subjected to very acute tectonic pressures exerted from the north-west and west, which have converted them largely into slaty shales and thrust them an unknown distance towards the south-east into the Baluchistan frontier regions.

While in the Quetta-Pishin district, they also examined the sections in and around the Ghazaband Pass (30° 19′ : 66° 49′) and are of the opinion that the junction of the isolated outcrops of the black Kirthar limestone and the underlying slaty shales is a tectonic one. They suggest that the slaty shales with thin sandstones to the north of these limestone outcrops are possibly equivalent to the Kojak shales, but that the much greater thickness of shales and slaty shales with thin limestones occurring to the south are of Triassic age, equivalent to the Triassic strata of the area around Wulgai (30° 40′ : 67° 29′) near the border with the Zhob district, east of Pishin.

Among the Triassic shales in the Saiyidwal *nala* 1½ miles south of Wulgai, they examined a much brecciated outcrop of dark grey

[1] *Rec. Geol. Surv. Ind.*, XXXVIII, Pt. 3, p. 202, (1909).

limestone containing upper Palæozoic fossils, *Productus*, crinoids, &c. Permo-Carboniferous limestone had previously been mapped in this area by Vredenburg. His maps, however, suggest a much wider occurrence than is actually the case, for the main ridge south of Wulgai is composed almost entirely of the shales and thin limestones of Triassic age.

Permo-Carboniferous limestone near Wulgai, Baluchistan.

In the General Report for 1937[1], it was mentioned that Dr. Dunn had noticed evidence in the Kolhan, South Singhbhum, suggesting that the Iron-ore Series and the Older Metamorphic Series were one and the same, and that certain conglomerates formed the base of a younger series. He has now definitely established that the basal sandstone-conglomerate, which had been originally accepted by H. C. Jones as the base of the Iron-ore Series, is at the base of a much younger series. Rocks which had been previously regarded as belonging to an 'Older Metamorphic Series' are now found to belong to the Iron-ore Series. The new younger series has been given the name 'Kolhan series.'

Kolhan series and Iron-ore series, Singhbhum, Bihar.

The Kolhan series consists, in descending order, of shales (phyllitic), limestones (lenticular) and sandstone-conglomerate (Jones's purple sandstone). This series rests, with marked unconformity, on the Singhbhum granite and on the Iron-ore Series. The unconformity was followed by Dr. Dunn, south-south-west from Chaibassa to Jagannathpur and west to Noamundi, from where it turns north towards Kantoria. Sections in railway cuttings and streams are excellent and the actual unconformity can be seen in many places, particularly at critical points. The Kolhan series overlaps in succession the Singhbhum granite, and lavas, tuffs, banded hematite-quartzite and phyllites of the Iron-ore Series. North of Noamundi mine the Kolhan series cuts at right angles across the strike of the Iron-ore Series. The Kolhan conglomerate usually contains large boulders of banded hematite-quartzite where it overlies, or is close to, banded hematite-quartzite of the Iron-ore Series.

Where it rests on a granite basement the Kolhan series is almost horizontal and undisturbed, but to the west, where it overlies phyllites of the Iron-ore Series, it is highly folded. The relative rigidity of the basement has partly determined the degree of folding.

[1] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, p. 27, 1938.

The main area of the Kolhan series is on the eastern side of the Iron-ore Series, but outliers of the basal sandstone-conglomerate have been infolded with the Iron-ore Series farther west, as at Gua and Jamda.

There is, in addition, a much later, very distinctive, friable grit which rests on top of all the other rocks. It may even be Tertiary.

The new sequence of sedimentary rocks may now be compared with the old :—

Jones.		Dunn.	
Iron-ore Series.	Upper shales, lavas,and ash beds		Kolhan shales.
	Banded hematite-quartzite		„ limestone.
	Lower shales		„ sandstone-conglomerate.
	Limestone		(unconformity).
	Purple sandstone-conglomerate.		
	(unconformity).		
Older Metamorphic Series . .		Iron-ore Series .	Phyllites.
			Banded hematite-quartzite.
			Tuffs, cherts, phyllites.
			Lava, tuffs, cherts.

The sequence within the Iron-ore Series, as given by Dunn, is uncertain but is probable on the available evidence.

In South Singhbhum, Dr. Dunn has been unable to find any intrusive contact of the Singhbhum granite with the Kolhan series. The evidence at the places quoted by Jones is either unsatisfactory or was previously incorrectly interpreted. The old land-surface is exposed at many places and everywhere suggests unconformity with the Singhbhum granite. The Singhbhum granite is, however, clearly intrusive into the Iron-ore Series. The full stratigraphy may be compared with the previous view :—

Jones	Dunn.
Newer dolerite . .	? Tertiary grit.
Ultrabasic intrusives .	Newer dolerite.
Granite . . .	Kolhan series.
Iron-ore Series . .	(unconformity).
(unconformity)	Singhbhum granite.
Older Metamorphic Series	Iron-ore Series.

The position of the ultrabasic intrusives is not yet determined.

Upper Senonian, Khasi and Jaintia Hills, Assam.

In the Assam plateau two sub-divisions are recognised in the Cretaceous, namely an upper one consisting of earthy limestones and calcareous shales associated with olive-coloured glauconitic sandstones, and a lower one, consisting of massive sandstones and conglomeratic beds. The upper division is highly fossiliferous and

fossils have been found in them at the following places; Amsyiem (25° 11′ : 92° 1′), Umjaha (25° 12′ : 92° 3′), Borghat (25° 10′ : 92° 14′), Bataw (25° 14′ : 92° 15′), in sheet 83 C/S.W. The following is a list of species provisionally identified in the collection:—

Pecten (*Neithea*) *faujasi* Pict., *Ostrea* (*Alectryonia*) *ungulata* Schloth, *Ostrea* (*Alectryonia*) sp. cf. *pectinata* Lam., *Gryphaea vesicularis* Stol., *Radula* (*Ctenostreon*) cf. *complanata* Stol., *Cardiaster* cf. *orientalis* Stol., *Hemiaster* cf. *oldhami* Noet., *Hemipneustes* sp. cf. *pyrenaicus* Hebert, *Turritella* (*Zaria*) *breantiana* d'Orb.

All the forms mentioned above are Upper Senonian, excepting the last, which ranges from Turonian to Lower Senonian. The age of the Upper Cretaceous fauna of Assam is therefore Upper Senonian. This view is in agreement with that of Dr. E. Spengler who decided on an Upper Senonian age for the Assam Cretaceous fauna. The majority of the forms present in Assam are common in South India and a few in Baluchistan.

EARTHQUAKES.

Paliyad, Kathiawar.

39. A series of tremors and shocks of varying intensity, accompanied by loud rumbling sounds, were felt at Paliyad commencing from the 26th June, 1938, the heaviest shock, which caused much damage to buildings, occurring on the 26th July 1938. Dr. H. Crookshank, who investigated the phenomena on the spot, ascribes the shocks to changes taking place beneath the Deccan trap formation of the locality, probably connected with the uplift of Kathiawar in recent geological times, which in places amounts to about 1,200 feet. No features such as faults are observable at the surface in the vicinity of Paliyad. Kathiawar by itself is apparently not liable to severe earthquake shocks, but the alluvial fringes may suffer if shocks of great intensity occur in the Indus valley, as was the case in 1819.

Punjab, North-West Frontier Province and Kashmir.

Many shocks of very light to moderate intensity have been reported from north-western India—the Punjab, Kashmir, North-West Frontier Province and Baluchistan. One of these, of moderate intensity sufficient to affect persons at rest and make hanging objects swing, was felt between 15-00 Hrs. and 15-05 Hrs. I.S.T. on the 18th January 1938 over a large area north and west of Lahore. No damage to property has been reported. Two other shocks of

a similar nature, one at about 16-15 Hrs. on the 26th January and the other at about 1-00 Hrs. on the 15th February, were also felt in several places in the North-West Frontier Province.

Assam.

A large number of tremors and light shocks have also occurred in Assam, in and around the plateau. None of these is, however, noteworthy.

Salem district, Madras.

Occasional shocks of small intensity (III-IV on the modified Mercalli scale) continue to be felt at Mettur in the Salem district, where the Cauvery river has been impounded by a large dam having a maximum depth of storage of 165 ft. and a net capacity of 93,500 million c.ft. of water. Only two shocks have been reported during the year, the first at 8-31 Hrs. on 25th November and the second at 3-03 Hrs. on the 14th December.

Burma.

The border zone between the Tertiary belt and the ancient crystalline rocks of Burma is a region susceptible to earthquakes. Htawgaw, not far from the China frontier in the northern corner of Burma, maintained its notoriety as one of the most seismic places in this country, by recording several scores of shocks during the year, some of which were fairly severe. The Upper Chindwin district and the Indaw oil field experienced a shock, strong enough to be widely felt and to produce some cracks in walls, at about 11-00 Hrs. (Burma Standard Time) on the 16th August, 1938.

The India Meteorological Department collects records from various meteorological stations in India, and from voluntary observers. These and the instrumental records by the seismographs at Calcutta, Agra, Colaba (Bombay) and Kodaikanal will be published by that department in its Annual Weather Review for 1938.

ECONOMIC ENQUIRIES.

Arsenic.

Drug district, Central Provinces.

Mr. B. C. Gupta reports lenticular lodes rich in arsenopyrite in the felsite near its junction with the granite batholith south of Handitola (20° 49′: 80° 39′). None of those seen were large enough to be of economic importance. The sulphide ore was assayed for gold, but gave negative results.

Bauxite.

Bastar State.

Dr. H. Crookshank reports bauxite associated with laterite on the Tarali Metta (18° 32′ : 81° 14′), and at the watershed between the Bailadila and Galli *nalas* one and a half miles south of the Bailadila Guest House (18° 44′ : 81° 14′). Specimens from these localities have been analysed by Mahadeo Ram in the Geological Survey laboratory with the following results :—

	Tarali Metta.	Bailadila Watershed
SiO_2	·26	1·34
Al_2O_3	62·96	61·85
Fe_2O_3	7·09	3·15
CaO	·06	·13
MgO	·05	·24
TiO_2	2·45	4·05
MnO	trace	trace
H_2O at 110°C.	1·08	·32
H_2O above 110°C.	26·12	28·96
	100·05	100·04
Sp. Gr.	2·51	2·41

The analyses indicate the presence of low-titanium bauxites of the Kalahandi type. The specimens analysed are first-class bauxites, but it would be unwise to assume that large quantities of equally good ore are available on the Bailadila range.

The laterite from which the specimens were obtained occurs about the 3,000 foot level on the Bailadila range and also caps the Tarali Metta. The margin of the laterite is covered with dense vegetation and has only been examined in a few favourable localities. It is therefore probable that bauxite occurs in other places besides those noticed. The existence of scattered occurrences of lithomarge at the base of the laterite were observed. These generally indicate the presence of bauxite in the overlying laterite.

The ore at the Bailadila watershed was not recognized in the field as bauxite. Dr. Crookshank's recollection of this ore suggests that there is a considerable quantity available, but how much and of what average quality, it would be impossible to say without further investigation. The ore on the Tarali Metta occurs as scattered boulders, and the quantity available was not determined. If ever a railway is built to exploit the iron-ore of the Bailadila Range, it would be well worth while to prospect the bauxite carefully.

Building Materials.

Marble, Khyber Agency, N.-W. F. P.

In January, 1938, Dr. A. L. Coulson paid another visit with Col. E. W. C. Noel to the marble quarries[1] at Shahidmena (34° 9′: 71° 17′) in the Mullagori country of the Khyber Agency, from where marble is being obtained for the new Council House in Peshawar. The quarries had progressed since his previous visits and it now appears that the dip of the stone is south-east into the hillside. The Mullagori road has been improved and the supplies for Peshawar are carted by motor-lorry with reasonable facility. It is understood that it would cost about Rs. 16,000 to make the old railway-line alignment fit for bullock-carts and lorries—the tunnels are good but the tributary streams of the Kabul river would have to be bridged.

Dr. Coulson visited the spring, Tauda Oba China, two miles up the Tauda Oba Khwar, which is at about 1,950 feet above sea-level, the level of the Kabul river at the foot of the marble quarries being about 1,140 feet. He estimated the flow of the spring at about 2-3,000 gallons of water per hour and the flow is said to be least in January and February. The spring occurs along the Tauda Oba Khwar fault, massive limestones (and marble) occurring to the E.S.E. and schistose rocks to the W.N.W. of the fault, these latter being highly crumpled and crushed. There seems little doubt that there was a large dislocation along this line, the arch of the anticline having broken and slipping having taken place. The fault does not cross the Kabul river, but seems to continue in a semicircular direction around the foot of the quarries hillside. The water of the Tauda Oba China could be utilised below the present quarries, but would require some two miles of pipe-line at a cost of about Re. 1 per foot.

Dr. Coulson inspected the marble that is being utilised in Peshawar. Complaints had been made that it was difficult to get a straight edge with the stone, but this would appear to be not the fault of the stone but of the masons, who were using very blunt chisels. Because of the difficulty of getting the marble quickly, the original design of the Council House had been altered and plaster over bricks was being used in some cases instead of marble. Some large blocks of more than six feet length were required and these were being obtained slowly by the primitive methods employed by the Mullagori contractors.

[1] *Rec. Geol. Surv. Ind.*, 71, Pt. 3, pp. 328-344, (1936) : 72, Pt. 2, pp. 227-234, (1937).

Dr. Coulson found some blocks of the marble near Shahidmena in the Tauda Oba Khwar, not *in situ* but obviously belonging to the rock that was being quarried. These were examined by Dr. M. R. Sahni, who states that one specimen shows crinoidal stem plates, etc., but none of the fossils is identifiable. Moreover, crinoidal stem plates are rarely useful for fixing geological horizons. Accordingly, though the specimens are very comparable with the Carboniferous limestone, definite proof of this age for the limestone (and marble) has yet to be obtained.

Calcareous tufa Kangra district, Punjab.

Mr. H. M. Lahiri notes the occurrence of large blocks of calcareous tufa in the Garelli Khad near Nagni (32° 18′ : 75° 57′) three miles east of Nurpur, Kangra district, which may be utilised as a source of lime. The deposit is small and the supply is limited.

Calcareous tufa, Udhampur district, Jammu, Kashmir.

Mr. P. C. Das Hazra reports the occurrence of several deposits of calcareous tufa in Udhampur district, Jammu, Kashmir. As there are no limestone beds in the area, these deposits may be suitably burnt to produce lime to supply the local need for mortar. The chief deposit of tufa is along the Nili Khad, west of Jib (32° 55′ : 75° 3′).

Road metal, Riasi and Jammu districts, Kashmir.

Mr. Das Hazra notes that the silicified Sirban limestone, which is easily available in any amount from the extensive scree deposits, is used as road-metal in the Riasi and Jammu districts, Kashmir.

Chromite.

Ratnagiri district and Savantvadi State, Bombay.

At the instance of the Bombay Government, Dr. L. A. N. Iyer reported on the mineral deposits of Ratnagiri district, and Savantvadi State. These occurrences have been mentioned in the *Bulletin of the Imperial Institute*, VIII, p. 401 (1910) and in the Institute's Monograph on Chromium Ore, p. 18 (1921). Dr. P. K. Ghosh of this Department visited them in 1933 and his account is given in the General Report for that year (*Rec. Geol. Surv. Ind.*, LXVIII, p. 30, (1934). Dr. Iyer investigated the chromite deposits long known to occur at Kankauli (16° 16′ : 73° 45′) and Vagda (16° 14′ : 73° 45′), and states that masses of chromite occur in serpentinous intrusions in these localities. As a result of his work he came to the conclusion that the chromite occurs in more or less horizontal

tabular lodes. He considered that about 50,000 tons of ore were in sight at Kankauli, and about 17,000 tons in three small lodes at Vagda. As the serpentinous intrusions probably extend downwards to a great depth, it is quite possible that there are other lodes not now exposed, but whether these could be easily located is uncertain.

Thirteen samples of ore collected from these localities were analysed in the Laboratory of the Geological Survey of India. The content of chromium oxide was found to vary from 31 to 39·37 per cent. The Vagda chromite proved to be slightly richer than the Kankauli, but both must be considered low-grade.

Attempts made by Dr. M. S. Patel of Bombay to enrich the ore succeeded in yielding a concentrate containing 50 per cent. of chromium oxide, 25 per cent. of iron oxide, and 2 per cent. of silica. Owing to its high iron content it proved impossible to market this concentrate.

Clays.

Fuller's earth, Jammu, Kashmir.

A layer, a few inches thick, of soft, waxy, sectile clay (fuller's earth) of a highly absorbent nature and of possible use in industry as bentonite, occurs in a clay bed interstratified with the Upper Siwalik conglomerates of Bhimber (32° 58′ : 74° 5′) Jammu Province.[1] The outcrop of the bed occupies a wide area and is traceable for some miles. A few hundred tons a year have been exported during the last few years, value about Rs. 60 a ton. There is a quick transition of the soapy grey bentonitic clay material into the ordinary red or blue Upper Siwalik clay and the quality of the product mined was found by Mr. Wadia to vary greatly.

Kaolin, Drug district, Central Provinces.

Mr. B. C. Gupta reports that white clay occurs in considerable quantities in the Cuddapah shales east of Harratola (20° 54′ : 80° 43′) Drug district, C. P. It is somewhat gritty, but on lixiviation yields a fine plastic clay which fuses below 1,400°C. This clay is locally used for whitewash.

Kaolin due to the decomposition of felsite and porphyry is extensively excavated for local use in the porphyry area west of Chandia (20° 53′ : 80° 54′). The unwashed material is plastic, and

[1] C. S. Middlemiss' "Non-Metallic Minerals of Jammu and Kashmir," *Rept. Min. Surv. Jammu, Kashmir*, Jammu, pp. 32-35 (1930).

fairly free of grit. Heated to 1,400°C. it contracted, but did not fuse nor crack. Its colour after heating was grey.

Kaolin, Khasi and Jaintia Hills district, Assam.

Kaolin is sometimes seen in association with the Cherra sandstones. It also occurs as an alteration product of the felspars in the gneisses and granites. The deposits are small, with a thickness varying from three to five feet. North-east of Laitksch (25° 29′ : 91° 25′) the kaolin is iron-stained and assumes a pisolitic structure.

Coal.

Langrin and Nongstoin, Khasi Hills, Assam.

The area examined this season lies in the south-western corner of the Khasi Hills between the Um Mawblei and the border of the Garo Hills, into which the coal-bearing strata extend (*see* sheets 78 O/S. W. and 78 K/S. E., ½″=1 mile). It was roughly examined in 1867 by Godwin-Austen (*Journ. As. Soc. Bengal*, XXXVIII, pt. 2, 1869) and more carefully by La Touche about a dozen years later (*Rec. Geol. Surv. Ind.*, XVI, p. 164, 1883; and XVII, p. 143, 1884). It was revisited in February, 1938, by Dr. Fox during the completion of the survey of the Garo Hills and adjacent areas in the Khasi Hills. It has been briefly discussed by Simpson (*Mem. Geol. Surv. Ind.*, XLI, p. 28, 1922), largely from La Touche's data, under the heading *Umblay river*.

The area is divided, structurally, into two unequal parts by a strong fault, throwing down to the east, which trends north-northwest from the debouchment of the Wah Rongah (25° 13′ : 91° 5′) to the western side of Kulang Hill (25° 15′ : 91° 4′ 30″) and northwards. The area to the west is entirely in the siemship of Nongstoin and is of greater extent than that to the east of the Kulang fault, which is largely in Langrin. The western Nongstoin area comprises difficult country in which the coal-bearing strata extend north-westwards to the Simsang river east of the Daranggiri coalfield. In thus striking inwards into the hills the coal measures of the west or Nongstoin area gradually recede from the plains of Sylhet.

The eastern or Langrin area is triangular in shape, with its point to the gorge of the Jadukata river below Lengar Bazar (25° 13′ : 91° 14′ 30″) and its base on the Kulang fault. It is a plateau of Cherra sandstones which slope southward with the

surface of the ground, but these coal-bearing beds bend over at the edge of the plateau and dip steeply into the alluvial plains of Sylhet. Along the margin of the hills, and more extensively to the south-west and west of this east or Langrin area, the Sylhet limestones and higher beds (Kulang Hill) come in over the Cherra sandstones. There is, however, an inlier of the sandstones north of Bagali Bazar a mile and a half from the plains and extending northward for three miles to Nongsibak (25° 14′ : 91° 2′ 30″).

By far the most important areas for development are those of the Langrin plateau east of the Kulang fault, where the Cherra sandstones are exposed with gentle dips a mile or so north from the southern edge of the plateau. Coal seams outcrop in almost every deep ravine that discharges to the Sylhet plains between Bagali Bazar (25° 12′ : 91° 14′) and the limestone outcrops beyond Barsaura (25° 12′ : 91° 11′) . Most of these streams, the Wah Rongah from Kulang, the Kolagai from Nongumsur (25° 14′ : 91° 8′), the Chari Chara, the Lakma Chara, and the Barsaura stream,—lie in deep gorges on the plateau and contain pebbles of coal from seams exposed in the cliffs on each side.

There appear to be three or four seams varying in thickness from 2 feet 6 inches to over 6 feet, but so far as Dr. Fox's personal investigations are involved he thinks there are two chief horizons, —one, about 150 to 200 feet below the top of the sandstone, of a three-foot seam of woody texture with much fossil resin and of rather impure quality, resembling the upper seam of the Garo Hills; the second is a softer, black coal in a lower seam, 300 to 350 feet below the top of the sandstone, averaging five feet of good quality caking coal. It will be necessary to put down a few borings to prove the seams, as the exposures are not clear enough for reliable measurements.

In the Langrin area coal outcrops have been met with up the Barsaura, Lakma, Umsur, Charigaon and Wah Rongah valleys within a mile or so of the hills from the plains, as well as at various places down the scarp facing the Kynshiang valley to the north, from W. S. W. of Rilang Market to beyond the Um Plu north of Kulang Hill. These exposures suggest that the coal seams are better developed towards the west than to the east and north. The area of the Langrin coalfield (east of the Kulang fault) is roughly twenty square miles and contains five feet of workable coal within 200 to 300 feet of the top of the sandstone of the sur-

face of the plateau. Under the limestone to the west, near the Kulang fault, the seam will be at a greater depth—possibly as much as 900 feet under Kulang Hill.

The quality of the coal that may be expected in the Langrin area (east of the Kulang fault) is shown by the following proximate analyses :—

—	Ash.	Moisture.	Vol. matter	Fixed carbon
Barsaura seam —	Per cent.	Per cent.	Per cent.	Per cent.
Top 18 inches	5·22	3·22	43·20	48·38†
Next 24 ,, ...	6·68	2·92	41·74	48·66†
Next 24 ,, ...	10·26	1·96	41·84	45·94†
Basal 18 ,, ...	68·98	1·82	21·18	8·02*
Upper Barsaura (1) 3 ft. 9 inches .	6·60	8·54	36·98	47·88*
Upper Barsaura (2) 4 foot coal . .	1·50	9·16	38·16	51·18*
Charigaon (1) 3 foot coal . . .	5·32	2·70	48·24	43·74†
Charigaon (2) 3 foot coal . . .	5·60	7·44	43·52	44·44*
Nongplu seam 3 foot coal . .	5·12	1·70	41·98	51·20†

* Does not cake. Sp. Gr over 1·35.
† Cakes strongly. Sp. Gr. under 1·35.

The reserves in the Langrin area of twenty square miles may be taken at roughly four million tons per square mile in a seam five feet thick. The total reserves in fairly flat-lying coal thus equal not less than 80 million tons in one workable seam. It seems useless to estimate for the other seams, as these would be lost in the normal methods of mining used in India.

With regard to the area west of the Kulang fault in Nongstoin it is at present unnecessary to consider the areas west of the 91° meridian of east longitude and north of the Um Bytit. The area thus defined is also about twenty square miles in extent, under which 5 feet of workable coal in one seam should be available within a depth of 300 feet of the surface, where the Cherra sandstones occur, up to 600 feet, where the limestones lie gently and up to 900 feet, where the rusty sandstones cover the flat-lying limestones. West of a line from the mouth of the Wah Rongah northwestwards the beds dip into a synclinal fold and rise again along an anticline having the same axial direction. This area under the rusty beds overlying the limestones would require special exploration, but it has not been included in the estimate given above.

The quality of the thick seam in this area may be gauged by the analyses[1] of samples from the Um Bytit and Pendengru given below :—

—	Ash.	Moisture.	Vol. Matter.	Fixed carbon.
	Per cent.	Per cent.	Per cent.	Per cent.
Um Bytit	3·66	3·16	51·14	42·04
Pendengru	8·28	1·36	48·60	41·76

The coal is of strongly caking quality. The reserves will be the same as in the Langrin area—*i.e.*, 80 million tons in one seam 5 feet thick. The prospects are probably better in this area west of the Kulang fault, although this Nongstoin area is not so well placed as that to the east, but it is well worth proving by a few bore-holes in the area of the Bagali-Bazar-Nongsibak inlier of Cherra sandstones.

Khasi and Jaintia Hills district, Assam.

Mr. P. N. Mukerjee examined thin seams of coal in the Cherra sandstones underlying Sylhet limestones near Sutnga (25° 22′ : 92° 26′). The main seam varies from two to three feet in thickness and is overlain and underlain by gritty sandstones. The whole is underlain by a second seam of coal, with carbonaceous shales, the total thickness being about a foot. A sample of coal analysed

in the Geological Survey Laboratory gave the following result :—

	Per cent.
Moisture	1·39
Volatile matter	44·43
Carbon	53·18
Ash	1·00

The coal cakes strongly and the colour of the ash is buff. Mr. Mukerjee reports a similar occurrence of coal near Bapung (25° 25′ : 92° 18′). The coal is not now worked but is used locally by the villagers.

Mr. P. N. Mukerjee also visited an occurrence of coal, a seam varying in thickness from one to ten feet, near Lakadong or Umlatdoh (25° 11′ : 92° 17′), in the Sylhet limestone stage. The coal is overlain and underlain by ferruginous gritty sandstones and the beds dip at about 5° towards the south. Besides the main occurrence mentioned, there are a few patchy outcrops of thin seams of coal round Umlatdoh. This is known as the Lakadong Coalfield, though no coal occurs near Lakadong. A sample of coal analysed in the Geological Survey Laboratory gave the following result :—

	Per cent.
Moisture	1·21
Volatile matter	41·56
Carbon	55·26
Ash	1·97

The coal does not make a compact coke but swells highly. The colour of the ash is dirty pink.

Coal was reported to occur in the Cherra sandstones at Nongriat (25° 38′ : 91° 27′) and Nonghrong (25° 37′ : 91° 21′).

Although a search was made, no coal could be found at the first licality. At Nonghrong Mr. A. M. N. Ghosh was shown a piece of coal, which was said to have been obtained in the neighbourhood of the village. Accordingly Mr. Ghosh made an excavation, with the help of the villagers, near the basal parts of the exposure of the Cherra sandstones coming immediately to the west of the village. This resulted in unearthing a thin coal seam which was, however, broken, owing to the disturbed conditions of the overburden of the sandstones. The coal was found to be lignitic, resinous and of poor quality and the prospect of obtaining coal in large quantity is not encouraging.

Copper.

Jashpur State, Eastern States Agency.

During his investigation of the gold in Jashpur State, Dr. Dey found traces of malachite and chalcopyrite in a small lens of quartz occurring in the granitic rock at a place locally known as Sonpahari, west of Dokra (22° 37′ : 83° 55′) and also in the gold-quartz vein at Bangaon (22° 32′ : 83° 54′).

Engineering and Allied Questions.

Tilaiya dam site Hazaribagh district, Bihar.

The site of a proposed dam across the Barakar river at Tilaiya, near Barhi in Hazaribagh district, was visited by Dr. J. A. Dunn. The dam will be about 115 feet above river-bed and about 1,200 feet between abutments. At the site, the river has cut directly across the strike of a quartzite ridge. The quartzites dip vertically, as also do mica-schists upstream; decomposed granitic gneisses crop out downstream. The quartzites are closely jointed so that thorough grouting will be necessary. As the ends of the ridge at the river banks are only 200 and 325 feet wide respectively, it will be advisable to keep the dam as far as possible on the upstream side of the ridge. The quartzite should be a suitable building material.

Proposed Brahmaputra Pandu-Amingaon Bridge.

In March 1938, Dr. C. S. Fox visited the site of the proposed railway bridge over the Brahmaputra river between the Eastern Bengal Railway terminus at Amingaon (26° 11′ : 91° 4′) and the Assam Bengal Railway at Pandu. He found that the alignment of the bridge had already been decided on, at a position over a mile below the present steamer crossing, where the river begins to spill after its rush through the rocky gorge above the steamer crossing. This position is similar to that chosen for the Kalabagh bridge across the Indus and Dr. Fox considers it a well chosen alignment. His opinion was specially desired in regard to supplies of fresh stone for concrete aggregate for the bridge. After examining the southern face of Agthori hill, west-north-west of Amingaon, and then seeing the quarries near Chutiapara station, five miles north of Amingaon, Dr. Fox considered that the Chutiapara rock was suitable for concrete aggregate. He thought that fresh Agthori hill stone might be superior in strength for blocks but

this did not imply any marked advantage in its use as concrete aggregate, so that the railway engineers could choose whichever stone was more economically procurable.

On the conclusion of his field-work in the Mardan district of the North-West Frontier Province, and at the request of the Engineer-in-Chief, Army Headquarters, Dr. A. L. Coulson proceeded in April, 1938, to Dalhousie in the Gurdaspur district of the Punjab in order to advise the military authorities concerning building sites in the Cantonment. He was fortunate enough to experience very wet weather in the early part of his visit and so was able to see personally the state of the drainage system.

Building sites, Dalhousie, Punjab.

After a general account of the geology of the area Dr. Coulson discussed in detail in his report the various factors affecting the stability of the hill-slopes of the Cantonment and the structures erected thereon. He pointed out that, owing to the general east-north-east dip of the shales of which the Balun spur is mostly composed, whilst the western slopes are relatively safe, extra care must be taken with regard to the northern and eastern slopes. The conditions pertaining on these northern and eastern slopes are very similar to those on Sher-ka-Danda at Naini Tal, where the paramount importance of drainage is recognized and there are over 90 miles of *pakka* drains. After noting the bad state of the drainage at Dalhousie, Dr. Coulson commented on the choice of building sites and the drainage of terraces formed for building sites. The liability of Dalhousie to destructive earthquakes of the severity of the Kangra earthquake of the 4th April 1905, was noted, and the desirability of building light earthquake-proof structures, in preference to heavy buildings, even if made earthquake-proof, was stressed. Dr. Coulson thought that the usual heavy rainfall and snowfall which the Cantonment experiences, combined with the unsuitability of certain heavy buildings, the repercussions on, and the alterations in, the delicate state of equilibrium of the hill-slopes due to former slipping, and lack of proper drainage facilities, are the fundamental causes of the serious subsidence and slipping that have taken place on the northern and eastern slopes of the Balun spur.

Dr. Coulson notes on the suitability of three proposed building sites, two of which were rejected, and five alternative sites were brought to notice. He made detailed recommendations with a

view to arresting as far as possible the still-continuing subsidence and slipping. In particular may be mentioned the fact that the safety of part of the top and of the eastern slopes of the Balun spur is bound up inextricably with that of the Balun Bazaar. The importance, therefore, to the Military Authorities, of regulating the building and drainage of the Bazaar, cannot be too strongly stressed and the urgency for attention to the present slipped areas in the Bazaar is very real. Much money must undoubtedly be spent on drainage. To skimp this is false economy as, if action is deferred, the resultant damage will be great and increased repairs will be necessary.

Dr. Coulson notes that it is essential to avoid disturbing the hill-slopes as much as possible and for this reason he suggests the total prohibition of grazing, grass-cutting, tree-felling (except where this is desirable) and removal of soil, shingle, shale and other rock on the northern and eastern slopes of the Balun spur. The activities of the road-gangs should be very carefully watched as they have had the bad habit of removing soil, shingle and shale from steep cliffs for road-surfacing purposes, thus initiating slipping, which takes place later when percolating rainwater has lubricated the cleavage planes of the shales which have had their surface-retaining support of grass and vegetation removed. A large gang of sweepers to keep drains and channels clear, with efficient overseeing to report upon and mend broken places, would pay for itself many times over.

Tube-wells, Mardan, Nowshera and Charsadda, N.-W. F. P.

At the request of the Electricity Department of the North-West Frontier Province Dr. A. L. Coulson examined the proposal for sinking tube-wells at the grid substations at Mardan, Nowshera and Charsadda.

The grid substation at Mardan (34° 12′ : 72° 2′) is just about a mile distant from the Kalpani river and is at an altitude of 1,014 ft. The evidence from wells in the neighbourhood shows that there are several clay beds separated by thin sands and gravel down to a depth of 190 ft. Below this depth water-bearing sands may be expected and the water may be at a sufficient hydrostatic pressure to bring it close to the surface. The water from the well (192 feet deep) in the compound of the Divisional Officer's residence showed bacteriological contamination, but this is attributable to surface water being allowed to drain into the well when

it was sunk. This well is only 22 feet above the level of the limiting barrier of Attock slates at the Attock gorge but this will probably help towards the equalisation of the quality of the underground water. It will, however, be desirable to tap the water at an intermediate depth which is sufficiently below the contaminating influences of the surface.

The proposed tube-well at the site of the grid substation will give an adequate supply of good water for the purpose of this station. But from the point of view of the water-supply to the town of Mardan Hoti and the cantonment, the sinking of tube-wells near the perennial Kalpani river will be advisable. Dr. Coulson recommends that the larger question of water-supply to the Mardan area be first examined before sinking any tube-wells at the grid substation. The most suitable site for sinking wells for the supply of the Mardan area will be near the well of Sant Karam Singh, north of the village of Baghdada, and nearer the Kalpani.

The grid substation at Nowshera is about three furlongs west of the northern end of the bridge of boats across the Kabul river in Nowshera (34° 0′ : 72° 0′). It is about 920 ft. above sea-level and a neighbouring well shows water-level at 24 ft. depth, which will be approximately 96 feet above the drainage barrier of Attock slates at the Attock gorge. Abundant and good water should be obtainable at the grid substation provided it is taken down to below the level of surface contamination. The site of the proposed tube-well is near the Kabul river. Care will have to be taken to eliminate surface contamination and an abundant supply of water should be available within a depth of 100 ft., but the well can go to a limiting depth of 120 ft.

The grid substation at Charsadda (34° 9′ : 71° 44′) is at the acute angle formed by the Rajjar and Mardan roads, just north-west of mile 17-1 from Mardan, at an altitude of 980 ft. The subsoil water level is 14 ft. below the surface (966 ft. above sea level). The proposed tube-well will first meet a succession of sandy beds and dominantly clayey beds further down. As the water-level is about 166 ft. above the limiting drainage level of the Attock gorge, abundant water should be available before this depth is reached. It should scarcely be necessary to sink the tube-well below 100 ft., but it can go down to 150 ft. if necessary. All precautions should be taken to protect the supply from surface contamination.

In response to a request from the Government of the Punjab in the Electricity and Industries Department, Dr. A. L. Coulson visited the Mianwali district of the Punjab in February, 1938, to report on the water-supply of the Isa Khel *tahsil.* Advantage was taken of his presence to report on certain areas in the Mianwali *tahsil* of the same district.

Water-supply, Mianwali district, Punjab.

Dr. Coulson's report has been published by the Superintendent, Government Printing, Punjab, at Lahore (1938) and, with additional details received later, has also been published as pages 440-466 of Part 4 of Volume 72 of these *Records.* Accordingly it is sufficient to record here that details of analyses of the sub-surface water, and of the strata met with when such bores were sunk, have been given. Also it was concluded from the records of the deep bores at Isa Khel (Kas Umar Khan) and Masit that a thick band of impervious clay is responsible for the artesian conditions developed at Masit. It was also concluded that the sweet water with the requisite hydrostatic head to produce these artesian conditions is derived from the high land between the Marwat and Khasor ranges south of the Kurram river, the chief tributary of the Indus river in the area under discussion. The Kurram river is regarded as the chief contaminating influence on the subsurface water near Isa Khel town, as its water, at times extremely saline, has been used for over two centuries for irrigation purposes.

At the request of the Engineer-in-Chief, Army Headquarters-Dr. A. L. Coulson carried out in January, 1938, a water-supply investigation in the Quetta-Pishin district of Baluchistan.

Water-supply, Quetta-Pishin district, Baluchistan.

During November, Mr. E. R. Gee visited Baluchistan to take part in an enquiry into the means of augmenting the water-supply of Quetta. The other members of the committee of enquiry included the Chief Engineer and Secretary to the Government of Sind, Public Works Department, and the Superintending Engineer, Public Health Circle, Punjab. The estimated minimum requirements of good quality water for Quetta are, approximately, 3 million gallons per day. The supply, at present, is almost wholly obtained by pipe-line from springs at Urak, some twelve miles east-north-east of Quetta. Being directly dependent on the rainfall, this source of supply, although sufficient to meet the demand during a large

Water-supply, Quetta, Baluchistan.

portion of the year, is very liable to fall short of the minimum figure during periods of drought.

Mr. Gee observes in his report that the additional available resources, from springs and river-beds in the vicinity, are very limited, and he points out that these also would be affected during periods of widespread drought. He, therefore, considers that a reservoir, capable of augmenting the supply in such an emergency, is essential. A surface reservoir—the Spin Karez project—had been planned by the local authorities. Mr. Gee, however, is of the opinion that such a reservoir would become silted up within a relatively short period of years, and he considers that the most satisfactory reservoir available is the underground supply of the sands and gravels that occur among the alluvium of the Quetta valley. In order to test these gravels, he recommends six bore-holes to a depth of not more than 300 feet within, or in the vicinity of, Quetta, and suggests, on the evidence of the geological structure of the Quetta valley and on the records of past bore-holes, that in some instances an artesian or semi-artesian supply may be encountered. He further recommends the examination of certain springs and gorges in the Quetta neighbourhood with the object of augmenting the present pipe-line supply to a limited extent and suggests the possibility of constructing loose rock and earthen dams in the narrow limestone defiles of the Sra Khula and Murree Brewery gorges in order to spread the normal flood supply over a much longer period of the year.

Water-supply, Ratnagiri district and Savantvadi State, Bombay.

Dr. L. A. N. Iyer examined a strip of country, 20-25 miles broad, in south Ratnagiri district and Savantvadi State, bounded to the east by the steep slopes of the Western Ghats and to the west by the sea.

This area is a part of the Konkan. Its annual rainfall is about 200 inches at the foot of the scarp, and varies from 250 to 400 inches along its crest. With such a heavy rainfall, there should be no serious problem of water-supply for the major part of the year, but this is a rolling hilly region, and consequently a large part of the rainfall drains away through numerous rivers into the sea.

The main geological formations of the area are (1) the Pre-Cambrian or Archaean gneisses and schists, (2) the Kaladgis, (3) the Deccan trap, and (4) laterite. The two last mentioned predominate in the north, and cover a large part of Devgad and Malvan *talukas*,

The trap cannot store much water as it is a very fine-grained, massive, impervious rock. The laterite is so porous that it allows most of the rainwater to seep through it. A water-table is, however, found at the contact of the laterite and the trap. Springs abound at this contact and most of the well-water is obtained from it; this is also the case at the boundary between the trap and the older rocks.

East of and above the Ghats, where the annual rainfall is less than 20 inches, the trap is covered by subsoil and soil from 15 to 30 feet in thickness. A certain amount of water is stored up in this subsoil. Most wells are sunk into it in order to tap its supplies of water. When this source of water proves insufficient, the wells may have to go deeper into the trap. In the Deccan trap, fissure planes, faults, old river beds, the vicinity of a dyke, symmetrical valleys, and the vicinity of river banks, offer favourable sites for digging wells.

The gneisses and schists occur in the south-west corner of the area. These formations also change to laterite or to a loose soil and subsoil due to sub-tropical weathering. This subsoil is favourable for the storage of water, but in the areas covered by the laterite the contact of the laterite and the original rocks offers a possible place for the storage of water.

The Kaladgis consist of sandstones, quartzites and granulites. These formations are also favourable for the storage of water.

Felspar.

Ratnagiri district, Bombay.

Dr. L. A. N. Iyer reports felspar deposits in several places in the Konkan, but the only one at all promising is a large intrusion of almost pure potash felspar near Kadaval (16° 8′ : 73° 49′). The felspar from this intrusion had been previously examined in the Geological Survey Laboratory, and had been found suitable for ceramic purposes. The occurrence is about two miles from the nearest cart road. This leads to the port of Vengurla about 27 miles distant.

Glass Sands.

Ratnagiri district and Savantvadi State, Bombay.

Kaladgi sandstones occur in many places along the coast in south Ratnagiri district and in Savantvadi State. These have been quarried for use in the glass industry along the Savantvadi-Vengurla

road, and also at Maldi (16° 12′ : 73° 36′) and Valaval (16° 0′ : 73° 39′).

Samples of them were collected by Dr. L. A. N. Iyer and analysed in the Geological Survey Laboratory with the following results :—

Nature of sample.	Locality where collected.	SiO_2	Fe_2O_3
Crushed sandstone .	Mile 74, Vengurla-Savantvadi Road	97·54	0·47
Crushed sandstone .	Mile 72·25 Vengurla-Savantvadi Road (Half a mile south-east of the road)	98·56	0·39
Sandstone . .	Maldi	93·48	0·28
Crushed sandstone .	Two furlongs west of Math-Kudal road, one mile from Math.	98·11	0·43

Dr. Iyer concludes that the crushed sandstones are suitable for bottle glass, and can easily be transported by sea to Bombay.

Gold.

A specimen of tuffaceous ropy rhyolite collected by Dr. A. L. Coulson from three-quarters of a mile north of Injan Dheri (34° 14′ : 72° 17′) in the Mardan district of the North-West Frontier Province gave very varying assays for gold content in the Laboratory of this Department. The first assay gave 4·3 dwts. of gold per ton; two further assays on the same powder, however, gave only 0·3 grains of gold per ton. It seems desirable to accept this low value, 0·3 grains per ton, as more probably representing the average gold content of the sample. The first result may have been due to one large grain of gold. Dr. Coulson will revisit the area and collect more samples for assay. The occurrence of gold here, even though in small amount, is interesting and suggests that the alluvial gold of the Kabul river and Kalpani *nala*[1] may have its origin in the Frontier suite of alkaline rocks to which reference is made elsewhere in this Report (p. 64).

Mardan district, N.-W. F. P.

In the latter part of the field-season Dr. A. K. Dey carried out an investigation of the gold deposits of Jashpur State. He confined his attention mostly to the banks of the streams where water would be available during the dry season. Several trial pits and trenches were put down at Jammunda (22° 39′ : 83° 58′), Bartoli (=Kerse : 22° 35′ :

Jashpur State, Eastern States Agency.

[1] A. L. Coulson, *Trans. Min. Geol. Met. Inst. Ind.*, XXXIII, Pt. 2, p. 193, (1937).

84° 0′), Kachuakani (=Duiri: 22° 35′: 83° 57′), Aonrijor (22° 34′: 83° 58′) and Dhorasand (22° 32′: 83° 58′) on the Ib river; at Gowarmara (=Lapai: 22° 37′: 83° 51′) and Beabal (22° 37′: 83° 52′) on the Maini *nadi*; at Dandajor (22° 38′: 83° 50′) on the Amjhor *nala*; at Turialaga (22° 29′: 83° 55′) on the Sonajor *nadi*; at Bangaon (22° 32′: 83° 54′) on the Mangarkunda *nala* and at Pharsabahal (22° 31′: 83° 55′) on a tributary of the Mangarkunda. At all these localities alluvial gold was found from the surface to the decomposed upper parts of the gneissic bedrock. But the principal concentration is in the 'buried' gravels overlying the granitic gneiss in the banks of the streams. The only exception to this statement is that of small pockets of residual gold in the superficial deposits at Bartoli (=Kerse), Dhorasand and Turialaga. Such gold has been derived directly from the disintegration of quartz veins in the country-rock without being transported far from its source. The gravel beds are from a few inches to 10 feet thick. They are covered by 1 inch to 29 feet of overburden consisting of soil, silt, sand and grit. The amount of gold carried by the 'buried' gravels and the residual deposits varies greatly from place to place but on an average it is about 1·9 grains per cubic yard. Though the mining of such low-grade grounds may be economically possible by the use of very expensive mechanical devices, it is extremely doubtful whether the quantity of gravels needed for their successful operation is available in the area. For, on the basis of the results of his investigations, Dr. Dey estimates a total reserve of 264,000 cubic yards of gravels in the banks of the Ib, Maini, Sonajor, and a few other streams, containing about 1,045 oz. of gold valued at £7,552 according to the current price of gold.

The patches of ground formerly worked probably contained from 3 to 5 grains of gold per cubic yard. Prospecting has shown that small pockets as rich as this are still common. The gold-washers of the State can probably locate and work such pockets more economically than could a company with its heavy overhead costs.

A large proportion of fine gold is lost by the method of washing practised. Dr. Dey, therefore, suggests the use of gold-saving devices. The use of mercury in the final stage of separation may lead to some saving. But sluice boxes with mercury added to the riffles of the lower or end boxes would be found, according to Dr. Dey, the most

effective equipment. For not only can these boxes be made on the spot from the timber locally available but by their use a very large amount of ground can be handled.

With the assistance of these innovations and aided by the present high price of gold, the local gold-washers would find the washing of gold a useful adjunct to their agricultural occupation.

Dr. Dey has been able to trace the source of the alluvial gold of Jashpur to the tourmaline-quartz veins which are genetically connected with the granitic intrusives. Crushing tests made at Bangaon yielded 1·3 grains of gold per ton of quartz. The assay made on eight specimens of quartz collected at random from the outcrops of veins at eight different localities showed a gold content ranging from a trace to 16 dwts. to the ton. Although, from the assay tests, some of the quartz veins appear promising as potential gold lodes, it is impossible to make any statements regarding their economic possibilities without knowing whether they persist in depths with their values. Such an enquiry will require more extensive prospecting than has hitherto been possible.

Bonai and Bamra States, Eastern States Agency.

Dr. M. S. Krishnan reports that gold is recovered from the alluvium of the Brahmani river at several places in Bonai and Bamra States. There is a small valley surrounded on three sides by hills, about one mile west of Khulundikudar (21° 34′ : 84° 56′), which attracts a number of gold-washers in the latter part of the monsoon. The Sub-divisional Officer of Barkot in Bamra State found, by employing thirty people for three days, that the total recovery of gold was a little over half a tola, which at the present price of gold (about Rs. 35 per tola) works out at 3¼ annas per washer per day. He was told also that tiny nuggets, of the size of mustard seed or rice grains, are occasionally found. Since this is a valley closed on three sides the gold must have been derived from the rocks immediately around it. These comprise quartzites and quartz-schists and altered basic igneous rocks. The quartzites show veins of secondary silica, while the basic rocks contain a little pyrite. A prospector employed by the State some time ago collected several samples of these rocks and had them assayed, but with negative results. As Dr. Krishnan found no definite indications of mineralisation in the rocks, he is of the opinion that the

gold may be disseminated in the rocks in minute quantities and may have become concentrated in the alluvial soil of the valley.

Mr. D. Bhattacharji reports that gold occurs in many of the streams in the area mapped by him, and is recovered every year after the rains by *sonjhars* who wash for it in favourable localities. He was able to establish the occurrence of primary gold only in one case, a quartz vein occurring near Tappa (21° 5′ : 80° 49′) in the Khairagarh State. An assay of a sample from this quartz vein by the Chemist of the Geological Survey of India showed 0·6 dwt. of gold per ton of quartz.

Khairagarh State, Eastern States Agency.

Ilmenite.

Ratnagiri, Bombay

Dr. L. A. N. Iyer reports the occurrence of small quantities of ilmenite in the bay south of Ratnagiri port (17° 00′ : 73° 20′). It cannot compare in any way with the rich deposits of Travancore.

Iron-Ore.

Bastar State, Eastern States Agency.

Dr. H. Crookshank reports that the mapping of the iron-ore deposits of the Bailadila range, Bastar State, is now complete. Ore-deposits large and rich enough to be worked economically occur in numerous places along the two high ridges which flank the range and on the watershed of the Malengar at the southern end of the range. The total ore reserves have been estimated to be at least 610 million tons of first-class ore. The largest deposits are two on the watershed of the Malengar, and one 2½ miles north of Loa. In these three deposits there are at least 400 million tons of ore.

The ore-deposits commonly form gigantic cliffs up to 500 feet in height, which cannot be sampled accurately without boring. Specimens of ore were collected every few yards along the base of the cliffs, up their faces, and from their summits. These specimens were not selected for their richness, but are average specimens of the cliff at the point at which they were collected. Series of specimens taken vertically up a cliff, or horizontally across it, were crushed, coned, and quartered in the usual way, and were later

analysed by Mahadeo Ram in the Geological Survey Laboratory. The following are the results :—

Location of the deposit.	Nature of the specimens analysed.	Per cent. of iron.	Per cent. of phosphorus.	Per cent. of sulphur.
1 mile N. W. of Bailadila Guest House (18° 44′ : 81° 14′)	Average of specimens collected up face of cliff.	68·30	0·11	0·04
Do. . .	Average of specimens collected along base of cliff.	68·44	0·12	0·03
2½ miles N. of Loa (18° 30′ : 81° 11′)	Average of specimens collected along base of cliff	68·30	0·065	0·05
Do. . .	Specimen of normal ore from top of cliff.	68·30	—	—
Do. . .	Poor quality ore from top of cliff.	66·92	—	—
Top of Hill 3996 (18° 37′ : 81° 12′).	Normal ore	68·85	—	—
Do. . .	Ore selected for its poor quality.	62·24	—	—
Slope S. W. of hill 3996.	Normal ore . . .	68·85	—	—
Do. . .	Normal ore . . .	69·12	—	—
Hill 4080 (18° 37′ : 81° 14′).	Normal ore from top of cliffs.	68·85	0·09	0·05

These analyses show the exceptionally high quality of the ores exposed on the surface. It may be that the quality of the ore falls off slightly in depth, but there can be no doubt that hundreds of million tons of ore running 68 per cent. of iron are available on the Bailadila range.

Magnetite was noted in small deposits ¾ mile south-east of Tedum Metta (18° 18′ : 81° 27′), along the stream one mile north-east of Suki Metta (18° 18′ : 81° 18′), and along the stream one mile west of Mulraju Metta (18° 17′ : 81° 18′). A specimen from the second locality was found to contain 65 per cent. of iron.

These deposits are associated with garnet-grünerite-schist, a rock which is found locally throughout southern Bastar, and probably also in southern Jeypore. If there are any large magnetite deposits associated with this rock they would be much more accessible than the hematite deposits of the Bailadila range.

Dr. L. A. N. Iyer visited the iron-ore deposit at Redi (15° 45' : 73° 44') in Ratnagiri district. He reports that hematite occurs on the top of the ridge south of the village in beds dipping 35 degrees N. N. E. This hematite passes into lateritic iron-ore towards the coast, and at the bottom of the hills. The ore-body is roughly elliptical in shape, more than a mile long, and from a quarter to half a mile in breadth. A sample of the ore from the top of the hill was analysed in the Geological Survey Laboratory, and contained 91·06 per cent. of Fe_2O_3 equivalent to 64·1 per cent. of iron. Sir L. L. Fermor[1] examined this deposit in 1912, and predicted an export trade from this part of India. Redi is eight miles from the port of Vengurla.

Ratnagiri district, Bombay.

During his survey of the Garo Hills Dr. C. S. Fox had noted small occurrences of banded magnetite quartzite near Dobu (25° 33' : 90° 42') and near the Simsang river about Songmagiri (25° 29' : 90° 39'), but none was considered of economic importance. In 1938, however, when closing his traverse across the Khasi Hills, he noted a run of magnetite-grünerite-granulite, often resembling the banded hematite-quartzite of Singhbhum, south-west of Ara (25° 50' : 91° 10'). Although there is no massive ore it is possible that a search further to the north-east on each side of the Boko *nadi* might prove more profitable.

Garo and Khasi Hills, Assam.

Mr. A. M. N. Ghosh came across pebbles and boulders of magnetite lying scattered on the top of a hill at ·5505, two miles and a half east of Rambrai (25° 39' : 91° 19'). The float of magnetite covers an area of about half a square mile. The occurrence seems to be superficial and limited in extent.

Lead-ore.

Mr. D. Bhattacharji reports small quantities of galena in quartz veins at Murhipar (21° 21' : 80° 53') in the Nandgaon State, and at Chhuikhadan in the State of that name.

Nandgaon and Chhuikhadan States, Eastern States Agency.

Manganese-ore.

In the southern part of sheet 73 C/6 in Bamra State, there are a few linear zones parallel to the strike of the foliation, which have been lateritised and

Bamra State, Eastern States Agency.

[1] *Rec. Geol. Surv. Ind.*, XLIII, Pt. 1, p. 18 (1913).

which contain lumps and nodules of manganese-ore. According to Dr. M. S. Krishnan they are found in the following localities :—

1. From Naktipali (21° 37′ : 84° 15′) to Phasimal (21° 36′ : 84° 17′).
2. From Phasimal to Tikiba (21° 34′ : 84° 20′).
3. From near Mukteshwar (21° 33′ : 84° 22′) to mile 22½ on the Jamunkira-Deogarh road.
4. East of Tiklipara (21° 32′ : 84° 27′).
5. From Kumbhiachhuan (21° 36′ : 84° 20′) to Sarai (21° 35′ : 84° 22′).

The manganese-ore is found as crusts on limonitised masses, as products of infiltration in cavities, and as rounded nodules with concretionary structure. The last type is the most abundant. A few veins are found in the limonite but they are unimportant. The ore is mainly pyrolusite with subordinate psilomelane, the latter being common in the crusts formed on lateritised rock. The distribution of the ore is sporadic, the flanks of the hillocks containing more than the tops. It may vary in amount up to two *maunds* (160 lbs.) per cubic yard. The most promising localities are near Khairdihi (21° 35′ : 84° 18′), near Rankibahal (21° 34′ : 84° 19′), Jamunkira (21° 32′ : 84° 23′) and near Tiklipara (21° 32′ : 84° 27′). Since the quantity found as nodules in the soil varies from place to place, it is not possible to estimate the amounts available in the different areas, without detailed knowledge as to the distribution of the ore. The depth of the soil also varies, but it is generally five feet or over and in some places may be even more than twenty feet.

Picked specimens of ore contain 50 to 54 per cent. of manganese, but the average recovered from the lateritised zones contains only 35 to 40 per cent., and is also ferruginous. The quality may, however, be improved by hand-picking. It seems that there is a prospect of obtaining a few scores of tons of saleable ore in the localities indicated. The railway is at an average distance of 25 miles from the deposits, and the distance to Calcutta (by rail) is about 330 miles.

Mica.

Mica was formerly obtained from a pegmatite near Kadaval (16° 8′ : 73° 49′), in Ratnagiri district, but it proved to be so brittle

and of such poor quality that the work has now ceased.

Ratnagiri district, Bombay.

Dr. Iyer states that there are books of mica two to three inches thick in the main felspar intrusion near that village. He considers that there is a chance of finding larger books lower down, as this is often the case in the mica-belt of Bihar.

Mineral springs.

Two occurrences of sulphurous springs have been reported by Mr. P. C. Das Hazra in Riasi district, Kashmir. The one which is situated about a quarter of a mile above Khar (33° 9′ : 74° 33′) along the Tawi river, discharges hot water only during winter. It precipitates a good deal of milk of sulphur. The other spring, Tattapani (33° 14′ : 74° 25′) is a well-known thermal spring. Its water is apparently possessed of certain therapeutic properties for curing skin-diseases and gouty affections. This spring is visited by a large number of people from far and near. The water gives a strong sulphurous odour and maintains a constant high temperature of 70°-80°C.

Sulphurous springs, Riasi district, Jammu Kashmir.

Sillimanite.

Sillimanite-rock was noted by Dr. H. Crookshank on the ridge half a mile east of Samsatti (18° 18′ : 81° 14′) and in the hills half a mile north of Chintaguppa (18° 15′ : 81° 14′). The occurrences are small and the sillimanite is much altered to sericite.

Bastar State, Eastern States Agency.

Dr. B. C. Roy reports a quarry at Dudkabahal (21° 57′ : 84° 15′) where flagstones of sillimanitic quartzite are obtained. As something similar is used for certain purposes in the blast-furnaces at Jamshedpur, and as this occurrence is only four miles from the railway, it may be of some economic importance.

Sambalpur district, Orissa.

Dr. Fox visited the corundum-sillimanite localities near Nongmaweit (25° 40′ : 91° 4′) in the Khasi Hills in February, 1938. The original mine was about a quarter of a mile N. E. of the northern village, but sillimanite has since been found in several places —(1) south of the Riangdo, ¾ miles N. N. W. of Nongmaweit;

Khasi and Jaintia Hills district, Assam.

(2) a mile N. E. of Nongmaweit (two deposits); (3) near Nongmawdam (25° 43′: 91° 7′); (4) bend of the Um Bain near Nongbain (25° 44′ : 91° 6′) and (5) an unconfirmed occurrence at lawjyrru on the Khasi Hills border two miles from Mansang (25° 40′ : 90° 54′) where corundum is said to be found. Dr. Fox's enquiries regarding Mawshinrut (25° 33′ : 91° 6′),—a name which means corundum in Khasi,—showed that no corundum is reported from Mawshinrut.

GEOLOGICAL SURVEYS.

North-Eastern Circle.

During the field season 1937-38 the North-eastern Circle consisted of Dr. C. S. Fox, Superintending Geologist (in charge), Mr. A. M. N. Ghosh, Geologist, and Messrs. P. N. Mukerjee and V. R. R. R. Khedker, Assistant Geologists. Mr. V. P. Sondhi, Geologist, also joined the North-eastern Circle in December 1938, on his return from leave in Europe.

Border areas of the Garo and Khasi hills, Assam.

Dr. Fox left headquarters for the field on the 11th December 1937, to complete his survey of the south-eastern corner of the Garo Hills in half-inch sheet 78 K/S.E. He traversed southwards from Damra (25° 56′: 90° 47′) through Dambu (25° 41′: 90° 50′) across the gneisses of the Garo Hills to Suangiri (25° 31′: 90° 48′) in the Nongstoin siemship of the Khasi Hills. Dr. Fox expected to meet a band of quartzite-magnetite rocks near Nongchram (25° 36′: 90° 49′) as he had found such rocks east of Dobu (25° 33′: 90° 42′) and near the site of Songmagiri (sheet 78 K/S.E.; 25° 29′: 90° 39′). Although Dr. Fox did not find these iron ores near Nongchram he has located quartzite-magnetite rocks among the gneisses south-west of Ara (standard sheet 78 O/1; 25° 50′: 90° 10′), when closing his traverse in February, 1938, on the anticipated line of strike (N. N. E. to N. E.). From Suangiri, where Dr. Fox first encountered the Tura (Eocene) beds,—sandstones, pipe-clays and coal-seams,—he examined the coal-bearing area known as the Daranggiri coalfield as well as its eastward extension into Nongstoin (Khasi Hills), where appreciable quantities of coal in workable seams occur. Dr. Fox carried his surveys southward to Pendengru 25° 15′: 90° 55′) and on to the Mymensingh plains about Pasgao

(25° 10′ : 90° 57′) where he found steep, southward-dipping Upper Tertiary sandstones with plant remains. Dr. Fox also noted the crest of an anticlinal fold in the Upper Tertiary beds in the east to west reach of the Mahadeo river at Thepthepgiri (25° 11′ : 90° 53′), but he did not observe any direct evidence of oil. He records the regular occurrence of at least two seams of coal in the Tura beds about Pendengru and Balphakram in the south-eastern area of the Garo Hills and considers that the lower seam is everywhere of workable thickness, although it frequently outcrops in very inaccessible places and with high dips.

Nongstoin and Langrin areas.

Dr. Fox continued his mapping eastward from the south-east corner of the Garo Hills into the south-western area of the Khasi Hills, bordering the plains of Sylhet, as far as the Kynshiang or Jadukata river (sheets 78 O/3, 4 and 8). Several outcrops of coal were discovered in this region over 70 years ago by Godwin Austin. These were revisited by La Touche half a century ago and it was then believed that a considerable quantity of coal must occur in this region. Dr. Fox has re-examined the chief localities mentioned by the two previous observers and several new occurrences which were brought to his notice during his survey. He records that all these coal occurrences, from Barsaura (25° 12′ : 91° 11′) and Lakma to Nongplu (25° 18′ : 91° 5′) and westward to the Garo Hills, occur in the Tura (Cherra) sandstones, which are regarded as of Lower Eocene age, and that 150 million tons of coal probably occur in one workable seam, averaging 4 feet thick, within a depth of 200 to 800 feet of the surface in the south-western part of the Khasi Hills. In the gorge of the Jadukata river the Tura (Cherra) sandstones are evidently underlaid by sandstones of uppermost Cretaceous age and these Mesozoic rocks in turn overlie beds of basaltic lavas and volcanic ash which are correlated with the Sylhet trap. Dr. Fox suspects a great W. N. W. fault, with northward throw, along the face of the scarp, facing the confluence at Rileng Market (25° 14′ : 91° 13′) from the south-west, as he found evidence of Sylhet limestone down the scarp when descending from near Nongmawhar (25° 13′ : 91° 11′) to the Jadukata river. Along the edge of the Sylhet plains from near Rajai (25° 12′ : 91° 14′) to Bagali Bazar (25° 12′ : 91° 4′) the coal-bearing Tura (Cherra) sandstones are overlaid by the Sylhet or Nummulitic limestones which dip steeply southward into the alluvium of the plains. Here,

at Charigaon (25° 11′ : 91° 7′) particularly, are the famous Langrin limestone quarries.

Westward of Bagali Bazar the Sylhet limestones are followed, along the edge of the plains, by the overlying Kopilis (alternations of clays and calcareous earthy sandstones), which dip south-westward at high angles and strike W. N. W. into the hills. Further westward, beyond Bangalbhita (25° 11′ : 91° 4′), and along the entire southern border of the Garo Hills, Upper Tertiary sandstones, often with high southward dips, occur along the outcrops at the edge of the plains. In only one place, half a mile east of Bagali Bazar, is there evidence of cross faulting, and in this case Dr. Fox was able to trace an important fault, trending N. N. W. with an eastward downthrow, which passes immediately west of Kulang Hill and which he has named the *Kulang fault.* The rocks of Kulang Hill (25° 15′ : 91° 4′ 30″), where Godwin Austin[1] collected fossils, were once known as the "Nongkulang hill series"[2] but have since been included in those which are now known as the "Kopili alternations stage" by P. Evans :[3] It is thus of interest that Dr. Fox finds that the rocks he has been in the habit of mapping as Kopilis—*e.g.* those between Rewak Songmong (25° 18′ : 90° 40′) and Siju Artheka (25° 19′ : 90° 41′) in the Garo Hills and elsewhere (as west of Bagali Bazar) are identical with those on Kulang Hill. Although Dr. Fox's collections of marine fossils from his Kopilis and from Kulang Hill have not been examined in detail there is little doubt that they will be found to be the same, and the age of the Nongkulang or Kopili beds may safely be regarded as uppermost Eocene to Oligocene[4].

Central and North Nongstoin.

After completing his examination of the Nongstoin and Langrin coalfields Dr. Fox continued a traverse northward through Nongstoin (25° 31′ : 91° 16′) to Nongmaweit (25° 40′ : 90° 4′) and Ara (25° 51′ : 91° 10′) and closed his survey near Singra (25° 57′ : 91° 10′) in February, 1938. From the confluence of the Um Mawblei and the Kynshiang river (25° 18′ : 91° 7′), where typical granitoid gneisses occur and a dolerite dyke was noted, Dr. Fox found that the Tura (Cherra) sandstones rapidly disappear to the north

[1] *Jour. As. Soc. Bengal,* XXXVIII, part 2, (1869).
[2] *Mem. Genl. Surv. Ind.* LI, p. 122, (1926).
[3] *Trans. Min. Geol. Inst. Ind.* XXVII, pp. 171, 173, (1932).
[4] Evans : *ibid.* p. 176.

as greater elevations are met with. Lum Langlieh (25° 23′ : 91° 6′) is an outlier of the sandstones and between Mawdumdum (25° 28′ : 91° 7′ 30″) and Nongstoin only occasional patches of kaolinized gneisses occur, while banded and granitoid gneisses, with rare zones of garnetiferous schist, are common. In the vicinity of Nongstoin itself there are coarse porphyritic granites and a coarse basic rock (? norite). The granite is younger than the basic rock but it is difficult to say if it is definitely intrusive in the foliated rocks,—gneisses and biotite-granulites,—of the region. Dr. Fox was able in two cases to examine the rocks in the beds of streams which follow curiously straight courses for a considerable distance, and found that in both a zone of shearing, if not definite faulting, was involved. Many observers have drawn attention to these remarkable rectilinear courses of some rivers of the Assam plateau (see sheets 78 O/7 and also 13) and it has been thought that joint-planes, across the foliation of the gneisses, were probably the structural factors involved. It would now seem that faulting must be admitted in some cases and the occurrence of block faulting may eventually be discovered.

Sillimanite and magnetite.

The strike of the biotite-granulites between Nongstoin and Patharkuang (25° 37′ : 91° 9′) is roughly E. S. E. to W. N. W., but further on, a mile north-west of hill 4126 (25° 38′ : 91° 8′), it is N. N. W., and from Nongpyriah (25° 39′ : 91° 6′) to Nongmaweit, the prevailing strike of the foliation of the granulitic gneisses is east by north. Around the camp of Nongmaweit in the loop of the Riangdo river (25° 41′ : 91° 4′), where the chief occurrences of corundum and sillimanite have been located, biotite-granites occur in a complicated association with the massive lenses and schistose bands of sillimanite rock. Lack of good exposures renders it difficult to elucidate the geology of the sillimanite lenses, but a careful survey may bring to light further occurrences of workable sillimanite. Dr. Fox has noted two new ones, in addition to the three already known near the original corundum mines (p. 54). Beyond Nongpur, where granulitic rocks appear, the foliation changes from E. N. E. to N. E. when hornblendic rocks occur. It is among these amphibolitic granulites on the ridge down from Nongkyndong (25° 48′ : 91° 7′) to near Ara (25° 50′ : 91° 10′) that Dr. Fox encountered a narrow belt of magnetite-grünerite-granulites closely resembling the hematite-quartzites of Singhbhum.

Khasi and Jaintia Hills district, Assam.

Mr. A. M. N. Ghosh worked in the unsurveyed tracts of the western Khasi Hills, mapping standard sheet 78 O/6 and portions of sheets 78 O/5, O/7 and O/11.

Gneisses.

Mr. Ghosh states that the dominant rock in the area is a gneissic granite varying from a fine-grained aplitic type to a coarsely crystalline porphyritic one. An unfoliated felspathic granulite occupies the floors of the deep gorges on the eastern side of the plateau. The different textural types are composed of quartz, microperthite, occasional microcline and variable amounts of oligoclase and biotite. Very often the felspars are found to enclose small rounded grains of quartz, which also occurs as blebs in felspars, as in *myrmekite.* Diopside may be found either alone or intergrown with hypersthene. Accessory minerals are pink garnet, apatite, zircon and rarely sphene.

Inclusions of garnet-quartz-rock, with or without sillimanite, are occasionally met with in the gneisses, also abundant basic rocks represented by pyroxene-granulite and amphibolite. The gneisses, as is indicated by the disposition of the basic inclusions, have been folded in places into the form of a horse-shoe.

Granites.

The gneisses are much intruded by porphyritic biotite-granites, having microcline as the principal felspar. In places the intrusion is so intimate that separation of the two rocks is difficult, but there are four large bosses of granite where the contact lines with the gneisses are sharp enough to admit of demarcation. The phenocrysts of felspar in the granites are mostly aligned approximately east and west, which is also the direction of the main vertical joints. The granites at Nongstoin (25° 31′ : 91° 16′) intrude large masses of norite and gabbro.

Basalt dykes.

Sills and dykes of basaltic rocks, presumably of Sylhet trap age, occur west and south-west of Rambrai (25° 39′ : 91° 19′).

Marine fossils in Cherra sandstones.

Small outliers of Cherra sandstone, sometimes carrying thin bands of lithomarge, have been found by Mr. Ghosh on the plateau. The small exposure at Nongkhrong (25° 37′ : 91° 21′) deserves special attention owing to its content of marine fossils. At this village the sandstone, only a few feet thick, is underlain by the gneisses and rests against laterite on its eastern side. The outlier is surrounded on three sides by gneissic hills and seems to have been preserved

in its present position through faulting. The sandstone is white, coarse-grained and contains pellets of kaolin.

The fossils collected by Mr. Ghosh consist of a few bivalves of which the forms *Arca*, *Corbula* and *Leda* could be recognised, some imperfect casts of gastropods and a coral (? *Trochocyathus*). Although the specimens are too badly preserved for specific determination, their general characters suggest a Tertiary age. Apart from a few fragmentary remains of bivalves and a solitary shark's tooth found by Mr. Ghosh last year in the Cherra sandstones on the western edge of the Cherrapunji plateau, no fossils, other than obscure plant remains, have hitherto been recorded in the Cherra sandstones. The present discovery of marine fossils at Nongkhrong is of interest, helping as it does to fix the age of the Cherra beds and to indicate the shallow-water marine conditions that prevailed at the time of their deposition. It is certain, therefore, that the early Eocene sea extended north of the central axis of the present Khasi Hills plateau and this is also indicated by the widespread distribution of isolated outliers of the Cherra beds.

Laterite and kaolin.

Mr. Ghosh records the presence of kaolin in the Cherra sandstones and suggests that kaolinisation of the gneisses, now found to be a common feature in the Assam plateau, is earlier than the Cherra sandstones. He also noted several exposures of ferruginous laterite, sometimes over fifty feet thick, capping the hills, and thinks that this type of laterite is chiefly associated with the basic bands in the gneisses. However, an aluminous type of laterite was noticed in iron-stained kaolin and shows the development of a pisolitic structure. Mr. Ghosh agrees with Dr. Fox that both lateritisation and kaolinisation of the gneisses commenced *pari passu* at the beginning of the Tertiary and these processes have possibly continued to the present day.

Khasi and Jaintia hills district, Assam.

Mr. P. N. Mukerjee worked in the Khasi and Jaintia hills district, Assam, and mapped a portion of the sheet 83 C/S.W., scale one inch to two miles. Exposures of granitoid gneiss of variable texture occur on the plateau and in the walls of the deep gorges.

Gneiss.

The rock is made up of quartz, plagioclase, microcline, green hornblende and biotite, with sphene and magnetite as accessory minerals. Foliation is evident, due to alternate layers of dark and light minerals, but at places is indistinct.

The gneisses are followed by the Shillong series, but the junction between the two is always obscure. The rocks are mostly quartzites and mica-schists, most intimately associated and usually highly contorted and folded. The beds strike east and west and dip very steeply towards the south.

Shillong series.

Two types of granite are recognised in the area, a coarsely crystalline pink granite, and a medium- to fine-grained grey granite. Thin sections show quartz, plagioclase, some microcline, biotite with a tendency to pass into chlorite, flakes of muscovite, hornblende, with magnetite and sphene. The granite is well jointed and on weathering forms huge tors.

Granite.

An outcrop of a Sylhet trap flow occurs in the Piyain Gang river, north of the Douki (25° 11′ : 92° 1′) bridge. The trap unconformably overlies the granite and is overlain by the basal conglomeratic beds of the Cretaceous. The trap is vesicular and contains amygdules of calcite, zeolites and green-earth. A very small outcrop occurs as a sill in the gneiss near Bataw (25° 14′ : 92° 15′).

Sylhet trap.

The Cretaceous beds unconformably overlie the gneisses, the granites and the Sylhet trap but are apparently conformably overlaid by the Cherra sandstones. Two subdivisions are recognised, an upper division, consisting of earthy limestones and calcareous shales underlain by olive-coloured glauconitic, felspathic sandstones, the whole succession being fossiliferous, and a lower division, consisting of massive sandstones and conglomeratic beds.

Cretaceous.

A considerable portion of the area is occupied by the Cherra sandstones, which overlie the Upper Cretaceous beds apparently conformably. The sandstone is mostly ferruginous and displays a great variety of colour. Where it is light-coloured, it strongly resembles the sandstones near Cherrapunji (25° 17′ : 91° 44′). Carbonaceous shales and thin seams of coal are sometimes found in the sandstone. The beds usually dip gently towards the south. Thin deposits of lithomarge derived from the decomposition of the felspars of the gneisses occur in the basal members of the sandstone.

Cherra sandstones.

The Sylhet limestone stage consists of beds of limestone separated by sandstones, conformably overlying the Cherra sandstones,

and underlying the Kopilis and other Tertiary strata. The limestone is generally impure and often highly siliceous, occurs both massive and bedded, is usually highly fossiliferous, and has caves, "swallow-holes" and other evidences of solution. The lithology of the sandstones in the Sylhet limestone stage is very similar to that of the Cherra beds, so much so that the demarcation of the boundary between them becomes extremely difficult when the limestone intervening between them is absent. Thin seams of coal occur in the sandstones of the Sylhet limestone stage near Umlatdoh (25° 11′ : 92° 17′).

Sylhet limestone stage.

The supranummulitics consist of bluish and greyish ferruginous shales, flaggy mudstones, siltstones and soft greenish grey sandstones, lying apparently conformably on the Sylhet limestones. In general, a lower argillaceous and an upper arenaceous facies can be recognised. The best exposures of these beds occur in the Hari and the Lubha river sections, where representatives of the Tertiary divisions, the Kopilis, Barails and the Bhubans of the Burmah Oil Company geologists[1], are well developed.

Supranummulitics.

Mr. V. R. R. R. Khedker mapped the central and western portion of sheet 78 O/13 and adjoining portions of standard sheets 78 O/14 and 78 N/16, scale one inch to one mile.

Khasi and Jaintia hills district, Assam.

Mr. Khedker considers that the oldest rocks in this area form part of a gneissic complex, the principal member of which is a fine-grained biotitic granitoid gneiss. Intimately associated with it are lenticular bands of hornblende-biotite-gneisses, which are fairly frequent in occurrence, particularly in the southern portion of sheet 78 O/13. Similar bands of cordierite-biotite-gneiss occur in two localities. The gneissic rocks are, on the whole, intensely foliated and crumpled. The general trend of the folds ranges from N. E.-S. W. to N. N. E.-S. S. W. Mr. Khedker has noted that porphyroclastic granulitic gneisses occur in isolated outcrops, along the foot of the Shillong plateau, and sheared biotitic gneisses occur in the vicinity of the junction of the Shillong series with the gneisses. These reconstituted rocks, although different in appearance from the above-mentioned

Gneisses.

[1] P. Evans, *Trans. Min. Geol. Inst. Ind.*, XXVII, Part 3 (1932).

types in this area, are, according to Mr. Khedker, probably their local modifications.

Overlying the gneisses are the Shillong series, whose strata are intensely folded and tilted; their regional strike is N. E.-S. W. with high dips in a south-easterly direction. Along the margin of this series the strata are particularly severely disturbed. In the Shillong series there are conglomerates, about two hundred feet in thickness, with pebbles and boulders of quartzite, embedded in a sericitic arenaceous matrix, which is schistose at places; quartzites which occur above the conglomerates and constitute a wide outcrop, interbedded with flaggy and clayey bands; above the quartzites and associated beds are the slates. Along the Shillong series and gneiss junction, the conglomerates apparently overlie the gneisses, from Japung (25° 39′ : 91° 51′) to Sumer (25° 42′ : 91° 53′). East of Sumer Mr. Khedker found the conglomerates cut off by faulting, and their place is taken by quartzites. Rocks of the typical Shillong series show the effects of a very low grade of metamorphism, whereas the gneisses are products of a distinctly higher grade of metamorphism.

Shillong series.

Around Nongpoh (25° 54′ : 91° 53′), there are large bosses and stocks of granite, which has intruded into the gneisses. On the whole the rock is very coarse-grained and highly porphyritic, although less porphyritic and uniformly coarse-grained varieties are also present. The granite around Nongpoh is lithologically very similar to the well-known Mylliem granite and also to outcrops of intrusive granite recorded elsewhere in the Khasi and Jaintia hills. Mr. Khedker thinks it quite likely that these granites belong to the same magmatic activity and are more or less contemporaneous.

Granite.

Magmatic emanations from the granite have effected a considerable amount of metamorphism in the adjacent portions of the gneisses by injections of veins and dykes. These have intimately invaded the country-rock, along all available planes of fissility, producing veined and '*lit-par-lit*' gneisses, which occupy the marginal zone around the granite outcrops, forming an aureole which is ¾ to 1½ miles in width.

Contact aureole.

North-Western Circle.

Dr. A. L. Coulson continued in charge of the North-western Circle until the 14th April, 1938, when he departed on leave out of

India. Mr. D. N. Wadia officiated in Dr. Coulson's absence from the 14th April till the 22nd October, and proceeded on leave on the 23rd October preparatory to retirement. Dr. Coulson resumed charge of the Circle on the 7th November, 1938, on his return from leave. The following officers conducted field work in the North-western Circle :—Dr. A. L. Coulson, Baluchistan, North-West Frontier Province and Punjab; Mr. D. N. Wadia, Kashmir; Mr. H. M. Lahiri, Punjab; and Mr. P. C. Das Hazra, Kashmir.

Mardan district, N.-W. F. P.

Owing to his prolonged economic investigations in Baluchistan and the Gurdaspur and Mianwali districts of the Punjab, and his visit of inspection to Mr. H. M. Lahiri in the Kangra district of the Punjab, Dr. A. L. Coulson was able to spend but little time in March, 1938, in the continuation of his geological survey of the Mardan district of the North-West Frontier Province. His work was mainly on sheets 43 B/3, 4, 7 and 8 on the Karamar range of hills to the north-east of Shahbazgarhi (34° 14′ : 72° 10′) but was sufficient to show a great development of rhyolitic, tuffaceous and porphyritic rocks. Four of Dr. Coulson's specimens of rhyolites and tuffs have been completely analysed and show more than 73 per cent. silica. Many of his specimens show aegirite and some show abundant soda-amphibole, possibly arfvedsonite. In this connection, reference may be made to his published description of other specimens of this Frontier suite of alkali rocks[1], some of which were collected from the area under discussion. Dr. Coulson has previously suggested a Mesozoic age for this Frontier suite, but much further work must be done before this can be substantiated or disproved. The relationship of the alkali rocks to the Buner granite[2] is still unsettled, but should be established in the coming field season.

Dr. Coulson noted certain outcrops of conglomerate near Jafar Kandao (34° 19′ : 72° 18′) between the Karamar range and the main mass of the Buner granite, and is hopeful that further tracing of their boundaries may give interesting results.

Mirpur district, Jammu, Kashmir.

During March, 1938, Mr. D. N. Wadia resumed his mapping of the Tertiary belt of the Jammu hills on sheets 43 G/15, 16; K/4, 8, 12; and L/1, in continuation of his Poonch survey of 1921-24. The area mapped falls within the districts of Mirpur and Riasi

[1] *Proc. Nat. Inst. Sci. Ind.*, II, No. 3, pp. 103-111, (1936).
[2] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, p. 86, (1938).

and serves to fill up, along with the mapping of the Udhampur and Jammu area, undertaken during the last two field seasons, and with systematic fossil collecting from the latter districts, an important *lacuna* between the Tertiary areas of Potwar and Kangra. The facies of Upper and Middle Siwaliks revealed in the 16 miles wide belt between Nowshera (33° 9′ : 74° 15′) and Mirpur (33° 11′ : 73° 46′) is analogous to the Potwar facies, the chief stratigraphic divisions,—Dhok Pathan, Pinjor and Boulder-conglomerate, being recognisable by their lithology, though identifiable fossil material is very scarce in this area. The older Siwaliks of this, as well as of the Udhampur and Jammu areas, mapped by Mr. Das Hazra, on the other hand, show greater resemblance to the variant facies of the Poonch Siwaliks, the Palandri and Mang stages. The markedly red shaly rocks which crop out anticlinally in the Nar-Budhan dome[1] (33° 24′ : 73° 49′) and 30 miles further south-east along the strike in another dome-like flattening of the same usually steep anticlinal fold, at Changi (33° 3′ : 74° 25′) are, Mr. Wadia believes, of the Mang horizon and therefore somewhat newer than Chinji. These rocks would represent the combined upper Chinji, Nurpur and lower Nagri horizons of the Punjab Siwaliks.

Three prominent strike-faults have been mapped in this area of broad open anticlines and synclines: (1) at the foot of the Kali Dhar line of escarpments, from the final eastward bend of the Tawi river to the valley of the Poonch; (2) at the foot of the high strike-ridge of Khandi from Kalal (33° 5′ : 74° 14′) to Panjan (33° 17′ : 73° 57′), where it dies out in an anticline; (3) the remarkably long dislocation limiting the Mang anticline of red rocks from near Riasi (33° 5′ : 74° 45′) on the east to near Nar (33° 24′ : 73° 48′) on the Poonch river. This last fracture disappears east of Riasi in an anticline of basal Middle Siwalik sandstones.

The main boundary fault between the Murrees (Lower) and Siwaliks has been traced from the Poonch border south-east, through sheets K/3, 4, 8 and 12. This fault makes an important tectonic feature of the area; it is a reversed fault with a plane of inclination varying from 30° to over 70°. A broad rib of Upper Murrees intervenes as a wedge, commencing from Seri (33° 19′ : 74° 4′) and stretching beyond Riasi at the foot of the Sirban (Great Limestone) inlier.

[1] C. S. Middlemiss, *Rec. Geol. Surv. Ind.*, XLIX, p. 191, (1919).

Mr. Wadia worked in the Riasi and Udhampur districts, in the Pir Panjal, on sheet 43 O/3. He notes that in the autochthonous belt of the Riasi Pir Panjal, only ten miles north of the great Riasi inlier of old unfossiliferous limestone, further evidence of the identity of the Jammu limestone inliers with the Permo-Carboniferous Sirban limestone of Hazara and of their contemporaneity with the Panjal volcanic series, has been obtained. From the Ans valley to beyond Batot (33° 7′ : 75° 17′) on the Chenab, an inlier of Dogra slate appears as the core of the recumbent anticline of Eocene, Panjal volcanics and Sirban limestone, unconformably underlying the latter. Over the slates comes a sequence of rocks strikingly similar to the Permo-Carboniferous sequence observed at Sirban, near Abbottabad, Hazara, commencing with a 100-300 feet thick boulder-conglomerate, resembling in every respect the glacial till of Tanakki. The conglomerate underlies a thick series of volcanic ash, tuffs, grits and quartz-agglomerates belonging to the bottom part of the Panjal volcanic series. At the top comes a 200-300 feet dolomitic limestone lithologically identical with the Sirban and Riasi rock, also containing repeated intercalations of volcanic matter. Good sections of this interesting assemblage are observed between Bhaj Khundi (33° 18′ : 75° 3′) and Anchah (33° 17′ : 75° 6′). Numerous facetted and scratched boulders and blocks occur enclosed in the fine silty matrix of the conglomerate, interbedded with tuffs and agglomeratic slates. The occurrence of a glacial conglomerate at the base of the great volcanic series of Kashmir suggests that the Permo-Carboniferous glaciation of the Salt Range and Hazara did affect the southern fringe of the volcanic region of Kashmir, although no signs of glacial action north of the autochthonous belt have been met with so far.

Riasi and Udhampur districts, Jammu, Kashmir.

In May, 1938, Mr. Wadia proceeded to survey the north-east flank of the Pir Panjal on sheets 43 K/5, 9, 10, 14 and O/2 in continuation of his previous work in the Uri and Karnah districts of Kashmir, and to join up some detached bits of mapping on this flank of the range with Mr. Middlemiss' important surveyed area of Banihal. The composition and stratigraphy of the Baramula rocks have been a controversial point; Mr. Middlemiss has mapped a broad belt of the Panjal volcanic series on the north side of the Jhelum near

Baramula district (Kashmir North) Anantnag district (Kashmir South), Uri and Muzaffarabad districts, Kashmir.

Baramula (33° 13′ : 74° 20′) and regarded the rocks in the road-cuttings on the south bank also as a variant facies of that series. Mr. Wadia's continuation of the survey of the Karnah *jagir* of the Muzaffarabad district and the Uri district to the south-east has convinced him that the Dogra slate and Salkhala zones of this area continue in force along the structural strike to as far as Baramula and are a little further south succeeded by the Panjal volcanics. At Baramula, among the prevailing Dogra slates, there is an interbedded metamorphosed chloritised trap, sometimes, in its more massive beds, resembling the Panjal trap, but of much older geological age.

A broad zone of repeatedly folded Panjal volcanic rocks, commencing from near Rampur (34° 9′ : 74° 10′) in Uri, strikes south-eastwards and forms the chief structural element of this flank of the Panjal range up to and beyond the Banihal pass (33° 30′ : 74° 13′). It abuts on the ancient slate series on its north-east margin with a mechanical contact and on the opposite side it is in conformable relations with the Tanawal (Gondwana) belt of Uri and Poonch. Field-work during the present season has revealed sections between Sarari (34° 8′ : 74° 14′) and Mingan Dor peak (11525) (34° 4′ : 74° 18′) which clearly prove a normal superpositional contact of the Panjal trap and slates over the Tanawals, as also noted by Dr. A. L. Coulson in 1937.[1] In this locality in numerous sections the Panjal trap flows and ash beds have been found interbedded with the quartzites, sandstones and phyllites of the latter series, which were provisionally referred to as Gondwanas by Mr. Wadia in his Poonch survey. A small oval patch of Tanawals entirely enclosed within a synclinal depression of the Agglomeratic Slates has been found north of the Budil pass (33° 30′ : 74° 40′). In a series of illustrative sections along the margin of this basin a transitional passage of the Tanawals into the Agglomeratic Slate, as well as into the Panjal trap, has been noted. It is evident from these sections that the Tanawals, though older in stratigraphic position than the volcanic series, do not differ considerably from them in age.

Acid and intermediate differentiation-products of the Panjal trap magma are of more frequent occurrence in this part of the Pir Panjal; rhyolitic and trachytic flows, finely porphyritic cerato-phyre-like lavas and acid tuffs of white, buff, purple and grey

[1] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, pp. 18, 89, (1938).

colours, are frequently associated with the more normal basaltic and andesitic lavas (epidotised) of the usual green colour.[1] In 1934 and again in 1936 a similar strongly marked, but localised, assemblage of acidic rocks was observed by Mr. Wadia in the Rajaori Pir Panjal between the Ratan Pir range and Thanamang (33° 28′ : 74° 28′).

An interesting structural unit on this side of the Panjal range is a remarkably persistent but narrow synclinal belt, over 55 miles long, composed of Gondwana, Permian (Zewan) and Upper Trias rocks; it is infolded with the Panjal trap, stretching from the Gulabgarh[2] pass (33° 29′ : 74° 54′) north-westwards along the main tectonic strike of the range to six miles north of Gulmarg,[3] where it attenuates to an isoclinal band of some 400 feet of Upper Trias limestone. The belt is widest, about four miles, between Tosha Maidan (34° 56′ : 74° 31′) and Chang (34° 51′ : 74° 31′), where it is also stratigraphically complete, containing, as the most constant units, a variable strip of the *Gangamopteris* beds, the richly fossiliferous Zewan series containing *Protoretepora*-bearing sandstones, and limestones with *Productus*, *Athyris*, *Camarophoria*, *Marginifera*, corals, etc., overlaid by over 2,000 feet of Upper Trias limestones; the central portion of the syncline is thrown into two or three compressed and severed folds, generally inverted to the south-west. The Lower and Middle Trias are absent and the Upper Trias is barren of determinable fossils, as is usual in the rest of Kashmir. The Gondwana beds generally contain fragmentary leaf impressions of *Glossopteris*, *Gangamopteris* and *Vertebraria*, the matrix being mostly volcanic tuffs, compacted and silicified. Unfortunately, except at Chang, much the greater part of this interesting belt along its entire length is concealed either under terminal and lateral moraine deposits of Pleistocene glaciers or by the Karewa deposits, with the result that only a few occasional glimpses of one or the other characteristic stratigraphic unit entering into its composition are all that is available for restoring the outline and strike-direction of this syncline. A new locality for Lower Gondwana fossil plants, including one with large fronds attached to the stem *in situ*, is Dandlutar (33° 31′ : 74° 59′) on the south-west limb of another similar syncline of Zewan strata preserved in the traps, six miles

[1] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, p. 88, (1938).
[2] *Ibid.*, XXXVII, p. 286, (1909).
[3] *Ibid.*, 73, Pt. 1, p. 89, (1938).

east of the Gulabgarh syncline. Between the Gulmarg-Gulabgarh syncline and the much wider Banihal syncline with its interesting band of Jurassic strata in the crest, mapped by Mr. Middlemiss, another syncline of Permian and Gondwana rocks, also mostly concealed under Karewas and moraines, has been mapped by Mr. Wadia, stretching northwards from Gaggar Mandu (33° 30′: 75° 0′) in the direction of Shupian Karewa. All the folds in the Banihal area having a pronounced pitch to the north-west, these synclines end abruptly in narrow wedges a little to the south of the crest of the range, while their broad ends are lost in the Pleistocene glacial and Karewa alluvium.

The completion of the mapping of the north-east flank of the Pir Panjal range has clearly brought out the synclinorial nature of the upper end of the Jhelum valley. The upper Jhelum basin contains five compressed and inverted synclines of Permian and Trias strata sunk into the Panjal trap, which builds the high bordering anticlinal ridges (the Pir Panjal and North Kashmir ranges) on either side of the valley. Underneath the Karewa and sub-Recent Jhelum alluvium the greater part of the Kashmir valley-bottom, above Srinagar, is composed of Triassic limestones, with possibly some Jurassic, resting on a floor of the Panjal volcanics.

During the present season the upper limit of the Karewas was found by Mr. Wadia to extend to a little above 11,000 feet, coming astride the lateral ridges and spurs up to the very foot of the central summit range. There is a prevalent north-easterly dip, but instances of irregular abrupt puckers and folds of small amplitude are not uncommon; a syncline with 40° dip in either limb is well exposed between hill Baribal (△8259) and the Yus Rest House, (33° 50′: 74° 40′). Another instance of irregular folding occurs in the Baramula Karewa 1½ miles north-west of the town. The higher reaches of the Karewas above 7,500 feet are covered under newer lateral and terminal moraines, only a few isolated patches being exposed by the erosion of the latter. The older moraines are intimately associated with the body of the Karewas. Fossil (carbonised) plant remains were observed at numerous localities, while lignitic clay intercalations are not rare. An interesting section throwing light on the physical conditions of the Karewa epoch is laid bare in the Botapathri Karewa (34° 5′: 74° 18′) containing beautiful black and white varves, about 80 to 100 within an inch. About ten feet of this clay, dipping 15° E., N. E. is exposed

at the surface, overlying the lignite seams of the neighbouring area of Linyan.

Kangra district and Chamba State, Punjab.

During the field-season 1937-38, Mr. H. M. Lahiri mapped, in continuation of his previous season's work, parts of sheets 44 M/13, 43 P/11, 12, 15, 16, 52 D/3, 7 and 8 lying mostly in the Kangra district but partly also in the Chamba State. Dr. A. L. Coulson paid a visit of inspection to Mr. Lahiri's area in February and March, 1938.

Except in the foothill region of the Dhaoladhar north and west of Dharmsala (32° 13′ : 76° 19′) where limestones and trappean rocks belonging to Medlicott's Himalayan series[1] occur in faulted contact with a series of sandstones and clays of probable Sirmur age, the geological formations mapped by Mr. Lahiri are the same as those in the adjoining area to the south and south-east described in the General Report for 1937.[2] The town of Dharmsala is situated on the Sirmur rocks.

The older Himalayan rocks in immediate contact with the Dharmsala beds near the town are grey or pink limestones probably of Krol age. Further north-west, however, the Himalayan rock in juxtaposition with the Tertiary sandstones is a highly altered trap rock, often amygdaloidal, of a basaltic composition. This latter rock is apparently the south-easterly continuation of the volcanic rock noted by McMahon[3] in the Dalhousie area.

The Dharmsala beds contain fine- to medium-grained sandstones with plant impressions at places. The upper strata of this group contain red and orange clays of the Lower and Middle Siwalik type and also a conglomerate, which all suggest a Siwalik age. Mr. Lahiri has, however, mapped them provisionally as Kasauli, pending the examination of these beds over a larger area than has hitherto been possible. The Dharmsala beds are faulted against Siwalik boulder-beds to the south and south-west, the fault running in a roughly E. S. E.-W. N. W. direction westwards from Dharmsala.

The Upper Siwalik boulder-beds immediately to the south and south-west of the above fault are well displayed in the hills with peaks 4,975 feet and 5,039 feet near the southern margin of 52 D/3

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 2, p. 17, (1864).
[2] *Rec. Geol. Surv. Ind.*, 73, p. 97, (1938).
[3] *Op. cit.*, XV, pp. 34-36, (1882).

and also north of Chari (32° 12′ : 76° 16′) in 52 D/8. In the southern part of 52 D/3, they are succeeded on the south and south-west by Middle Siwalik beds and these, in their turn, by Nahan or Lower Siwalik strata, the last being the continuation of the Nahans of the Bohar Kawalu (32° 5′ : 76° 12′) ridge of 52 D/4. As in the area immediately to the south-east, the Nahan beds of this area are faulted against Upper Siwalik strata on the south-west. This fault, the Gumber fault of Medlicott,[1] is, however, mostly concealed in the present area under a thick deposit of sub-Recent beds which occupy a large tract of ground in the south-eastern quarter of 43 P/15.

South-westwards from this fault there is, in 43 P/15, a regular succession from the Upper down to the Lower Siwaliks, the latter forming the ridge on which Nurpur (32° 18′ : 75° 53′) is situated. The Nahan beds are folded in an anticline which is the north-westerly continuation of the Mastgarh anticline of the north-eastern corner of 43 P/16. The Middle Siwalik strata of the south-west flank of the Nurpur anticline are separated, near the city, by a strike-fault which extends north-westwards to the Chakki Khad and beyond. The hills with peaks 2,184 feet and 1,886 feet south and west respectively of Nurpur are composed of Pinjor boulder-beds. The upper strata of this group exposed in the areas to the north-west and west of Nurpur dip at very low angles towards the south-west, whilst the dips of its lower strata, as well as of the underlying Pinjor sand-rock and Middle Siwalik beds, are invariably steep.

The general structure of the Siwalik range lying in the south-western part of 43 P/16 and its adjacent parts of 43 P/12, P/15 and 44 M/13 is a north-west pitching anticline, the north and north-east flanks of which are occupied by Pinjor boulder-beds characterised by low dips. The strata of the south-west limb in 43 P/12 have high south-westerly dips as a rule. The anticline is broken, on its south-west flank, by a prominent strike-fault (the continuation of the Satlitta fault)[2], as a result of which the highly disturbed Siwalik (mostly Pinjor sand-rock) strata of the plainward edge of the range are seen pushed on undisturbed sub-Recent and Recent deposits of the right bank of the Beas river in 43 P/16. This fault is traceable up to Indpur (32° 9′ : 75° 44′), further north-west of which it is concealed under alluvium.

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 2, p. 134, (1864).
[2] *Rec. Geol. Surv. Ind.*, LXVIII, p. 67, (1934).

Mr. Lahiri notes that, at Diothi (32° 3′ : 75° 50′), the Middle Siwalik strata of the south-west fringe of the Siwalik range are thrust on to boulder-gravels which lie on the denuded surface of the sub-Recent beds, and which are, therefore, much younger than the latter. The thrusting appears to have occurred along the previously existing fault-plane in post-Pleistocene or Recent times.

The Siwalik rocks of the area examined by Mr. Lahiri during the season are only sparingly fossiliferous. The Nahan rocks yielded *Chalicotherium* cf. *sivalensis*, *Hyoboops palæindicus*, *Aceratherium* sp. and *Hipparion* sp. A few fragments of Mastodon teeth are all that were obtained from the Middle Siwaliks, whilst the Upper Siwaliks (Pinjor sand-rock) yielded *Merycopotamus dissimilis* beside some suine and antelopine teeth.

Some fossil bovine teeth were obtained from the sub-Recent deposits near Malahri (32° 7′ : 75° 46′).

Mr. P. C. Das Hazra's field-work during the season 1937-38, was conducted in several distinct areas and included an extended period of work in the Uri Himalayas. The areas surveyed by him during the field-season are comprised in the following one-inch topographical sheets: 43 J/4 ; K/8, 12 and 16 ; L/5, 9, 13 and 14 ; and P/1.

Poonch district, Jammu, Kashmir.

Mr. Das Hazra opened the field-season in November, 1937, with a visit to the Poonch district in order to compare the Lower Siwaliks and the Upper Murrees with the corresponding rock formations in the Jammu district. The characteristic Lower Siwalik stages of Poonch, *viz.*, the Palandri and Mang stages, were studied in their type localities at Palandri (33° 43′ : 73° 41′) and Mang (33° 48′ : 73° 38′) and the Upper Murrees in the Mendhar valley.

Jammu, Udhampur and Riasi districts, Jammu, Kashmir.

In January, 1938, Mr. Das Hazra continued his former work in the Jammu, Udhampur and Riasi districts of Jammu. In addition to the geological formations given in the General Report for 1937,[1] extensive exposures of the Sirban limestone and Nummulitic Shales were mapped. As a result of his comparative field-studies in Poonch and Jammu, Mr. Das Hazra concludes that the Lower Siwalik formations in these two areas belong to the same palæo-geographical province and that the classification which has

[1] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, p. 95, (1938).

been adopted for the Lower Siwaliks of Poonch, and has been given above, should provisionally be adopted for the Lower Siwaliks of the Jammu hills until the intermediate area between Udhampur and the Gurdaspur district of the Punjab has been mapped. Although the standard sub-divisions were adopted for the Lower Siwaliks of Jammu by Mr. Das Hazra in the field-season 1936-37, several anomalies were observed, which he could not then explain. The Kamlials were found to exceed greatly their standard thickness, *e.g.*, in the Tawi section of Udhampur a thickness of 4,000 feet was obtained and it was difficult to separate the basal beds of the Chinjis from the top beds of the Kamlials on lithological grounds. In addition, the Chinjis sometimes contained fairly dark, thick-bedded sandstones. These abnormalities can easily be explained by grouping the Kamlials and the basal beds of the Chinjis together to form the Palandri stage and by renaming the modified facies of the Chinjis, with some basal beds of the Nagris, as the Mang stage. The highly calcareous nature of the clays, shales and sandstones, which often enclose thin, impure bands of limestone or marl, suggests that the Lower Siwaliks of the Jammu hills, like the Lower Siwaliks of Poonch, are partly of lacustrine and not wholly of fluviatile origin. The Lower Siwaliks are poor in fossils, but Mr. Das Hazra succeeded in finding a richly fossiliferous locality around Tara (32° 50′ : 75° 00′). Among the identified fossils collected during the season are the following (see p. **21**) :—Lower Siwaliks ; **Dinotherium indicum* Falc., *Mastodon* cf. *sivalensis*, *Aceratherium sp.*, **Tetrabelodon* cf. *angustidens* Cuv., **Conohyus* cf. *sindiensis* Pilg., *Stegodon* sp., *Giraffokeryx* cf. *punjabiense* Pilg., *Cervus* sp., *Listriodon* sp., *Rhinoceros* sp., *Chalicotherium* sp., Middle Siwaliks ; *Stegodon bombifrons*, *Mastodon* sp., *Tragocerus* sp., *Hippohyus* sp. ; Upper Siwaliks ; *Boselaphus* sp., *Bos*, *Elephas planifrons*, *etc.*

A considerable development of the Upper Murree stage has been mapped by Mr. Das Hazra in the Udhampur and Riasi districts. While there is little difference lithologically between the Upper Murrees of Jammu and Poonch, the Upper Murrees of the former area are distinctive in their yielding remains of vertebrates in addition to plants. A prominent ossiferous clay-conglomerate, about three to four feet thick, at Anji (33° 4′ : 74° 53′) and red shales at Gan (33° 6′ : 74° 44′) have yielded *Progiraffa* sp. and ubiquitous chelonian and crocodilian remains. Leaf and stem

* Indicates Kamlial Horizon.

impressions of ? *Sabal major* and other unidentified dicotyledons were obtained.

Riasi and Mirpur districts, Jammu, Kashmir.

From the middle of March, 1938, till the end of May, Mr. Das Hazra assisted Mr. Wadia in completing the mapping of the Tertiaries of the Riasi and Mirpur districts. Mr. Das Hazra also traced the southern, as well as a portion of the northern, boundaries of the main Sirban limestone inlier of Riasi. The smaller and detached inliers of the Sirban limestone, with fringes of the Nummulitic Shales carrying the coal-fields of Rajauri *tahsil*, Jammu, were also mapped. Mr. Das Hazra noted the Agglomeratic Slate as intercalations in the Sirban limestone in Mari *nala* (33° 6′ : 74° 52′), Riasi. The slate is black, compact, characterized by high density and is usually magnetic. According to Mr. Wadia, who visited the site later, this occurrence of the Agglomeratic Slate is better exposed than in the Sumlar area (33° 23′ : 74° 3′) in Kotli *tahsil*, Jammu. At Bobbian Gala (33° 12′ : 74° 28′) and Amali Gala (33° 12′ : 74° 32′) Mr. Das Hazra has noted the occurrence of the Fatehjang zone in the Lower Murrees, which has yielded chelonian and crocodilian remains.

The major tectonic features in the Jammu area are the main boundary fault between the Murrees and the Siwaliks, several strike-faults and a succession of anticlinal and synclinal folds. The main boundary fault has been traced through sheets 43 L/13, K/16 and K/12. In sheet K/16 the thrust-plane is obscured on account of its being covered by the Sirban limestone scree and also because of a great reduction in the width of the Murree outcrop. As reported before,[1] the inclination of the thrust-plane varies from 30° or even less, to about 70°. Of the two pitching Lower Siwalik anticlines of Udhampur, the Dursuh-Chenas anticline, limited in the south by the Kishanpur reversed fault, terminates below the foot of the Sirban limestone inlier in the north-eastern corner of sheet 43 L/13, but the Mansar-Suruin Sar anticline continues north-westwards, though much reduced in width of outcrop, on account of pitch. In sheets K/16 and K/12 only the Mang stage is seen, Palandris being totally eliminated. A prominent strike-fault separates the northern limb of the second anticline from the Middle Siwaliks. Near the crossing of the Chenab, the zone of the Siwalik rocks shows an abrupt deflection in the direction of the regional strike, which changes from N. N. W.-S. S. E. to E.-W.

[1] *Rec. Geol. Surv. Ind.*, 73, Pt. 1, pp. 92-93, (1938).

From June, 1938, till the end of August, Mr. Das Hazra assisted Mr. Wadia in mapping the northern slope of the Pir Panjals, Uri district, Kashmir. His work on sheet 43 J/4 was chiefly to revise and remap the previous reconnaissance survey. A strong development of an uncommon quartzitic facies in the Salkhala series was seen around Chitti-batti (34° 2′ : 74° 10′). According to Mr. Wadia, this quartzite bears a strong resemblance to the Boileaugunge quartzite of the Simla Hills. Intercalations of thin ash beds in the Tanawal quartz-phyllites were noted by Mr. Das Hazra near Rampur (34° 9′ : 74° 10′).

Uri district, Kashmir.

Southern Circle.

The Southern Circle consisted of Dr. H. Crookshank, Superintending Geologist, in charge, Dr. M. S. Krishnan, Dr. P. K. Ghosh, Dr. B. C. Roy, Geologists, Mr. D. Bhattacharji, Mr. B. C. Gupta, Dr. L. A. N. Iyer and Dr. A. K. Dey, Assistant Geologists.

Dr. H. Crookshank continued his work in Bastar State. He completed the mapping of sheet 65 F/7, and the western parts of sheets 65 F/2 and 3. The mapping of the area between the Eastern Ghats and the Bailadila range is now complete, and a detailed description of this region is in course of preparation.

Bastar State, Eastern States Agency.

Sheet 65 F/2 includes the southern end of the Bailadila range. The Iron-ore series, whose presence is the *raison d'être* of this range, dies out two miles north of Vengur (18° 33′ : 81° 12′). An outlier of the series is, however, preserved on the Tarali Metta (18° 32′ : 81° 15′), 1½ miles south-east of that village.

South of latitude 18° 50′ the Bailadila range consists of two high ridges separated by a valley. The Iron-ore series caps the ridges, but older rocks are exposed on their flanks, and down the central valley. It is thought probable that the high ridges are synclines, while the valley separating them is an anticline. The two synclines of banded hematite-quartzite are the vestiges of an once widespread formation.

Water circulates freely in the rocks of the Iron-ore series, but with difficulty in the older rocks underlying them. This is proved by the commonness of springs and swamps at the base of the Iron-ore series. It is considered probable that the extreme concentration of iron-ore along the high synclinal ridges is not an original feature of the Iron-ore series, but has been brought about

by circulating surface waters which have transferred most of the iron from the once widespread iron-ore formation to the deep synclines of that formation, the only parts of it which have survived denudation.

An interesting rock not previously seen in Bastar occurs extensively in the Galli valley north-east of Loa (18° 30′ : 81° 11′). It is dark green and full of water-worn boulders as large as a man's head. It also contains numerous angular chips of hematite-quartzite and shale which have escaped attrition. The boulders are mostly quartzite, but there are a few composed of very porous greenstone resembling pumice. The matrix is mainly quartz and fibrous hornblende. The rock is either a conglomerate or an agglomerate. It is phyllitic with schistosity parallel to the general strike of the area. Its true bedding is now lost, but must have been more or less horizontal, for bands of horizontally bedded chlorite- and biotite-quartzite are often associated with it.

Ranchi district, Bihar.

Dr. M. S. Krishnan spent the earlier part of the season mapping the strip of the Iron-ore series lying in the south-eastern part of sheet 73 B/14, thus continuing the mapping of Gangpur State northward to the boundary with the granitic rocks of southern Ranchi.

As in the adjoining areas, this strip of Iron-ore series consists of intercalations of mica-schists and metamorphosed basic rocks. The general strike in this region is E. N. E.-W. S. W., though in the south-eastern corner it becomes N. W.-S. E. over a small area. The dip may be vertical or steep in either direction.

The mica-schists are muscovite- and biotite-bearing, with variable amounts of quartz. Garnetiferous varieties are fairly common. The basic rocks comprise amphibole-schists (including tremolite- and, rarely, anthophyllite-schists), amphibolites and epidiorites. They are frequently penetrated by pegmatite and quartz veins.

The marginal zone, where the schists are in contact with granite, is characterised by composite gneiss. Away from this zone and to its north, the granite is massive and unfoliated. Pegmatite and quartz veins are common both in the granite and in the Iron-ore series, tourmaline being a characteristic mineral in them. In the western part of the marginal zone there is a large sill of aplitic rock which has been epidotised to a considerable extent.

A rapid reconnaissance of the Bamra State was made by Mr. H. Cecil Jones and Dr. M. S. Krishnan in the year 1925 for the purpose of gaining an idea of the mineral deposits present therein, and an account of the work will be found in the General Report for that year (*Rec. Geol. Surv. Ind.*, LIX, p. 64, 1926). Since then a considerable area in Singhbhum, Gangpur State and adjoining regions has been geologically surveyed. In continuation of this work, Dr. Krishnan commenced the survey of Bamra State in January, 1938, with the assistance of Dr. B. C. Roy. After introducing Dr. Roy to the geology of the area and working with him for a time, in sheet 73 C/5, Dr. Krishnan proceeded further south and mapped about two-thirds of sheet 73 C/6, while Dr. Roy has practically completed 73 C/5, which includes part of the district of Sambalpur.

Bamra State, Eastern States Agency, and Sambalpur district, Orissa.

The rocks found in this region have been tentatively classified as follows :—

Recent and Sub-recent .	Laterite and alluvium.
Precambrian . .	Dolerite, gabbro and pyroxenite. Granite (gneissic).
Iron-ore series . .	Altered and metamorphosed basic rocks (amphibolites and epidiorites). Mica-schists, quartzites and quartz-schists.

The mica-schists and quartz-schists, which are the oldest rocks in this region, are particularly well exposed in the north-eastern part of sheet 73 C/5, but must once have extended over the whole of the area. They were intruded by sills and dykes of basic igneous rocks and all the formations were then involved in a major dis-astrophism of the Archæan era, the basic rocks being converted into amphibolites, etc. Towards the close of the period, there was an invasion by granitic magma on a large scale, which displaced and assimilated the earlier rocks to a large extent. Remnants of the schists are now found as inclusions and streaks in the granite, which has also acquired a banded and gneissic character. The gneissic granite is composed of quartz, orthoclase, microcline, acid plagioclase, a little mica and hornblende. The included patches of mica-schists show the development of garnet at the contact, and in one case the formation of sillimanite-cordierite gneiss.

The presence of basic rocks of a later age is attested by dykes and sills composed of dolerite, gabbro and pyroxenite traversing the granite. They have been somewhat altered, the pyroxene having been converted to uralite in varying degrees.

Since that period, there has been no important geological change in the area except prolonged denudation and weathering. It is however known that Gondwana rocks of the red sandstone facies (either of Kamthi or Mahadeva age) occur a few miles to the south of the area mapped.

The general direction of schistosity, gneissic banding and fold axes is W. N. W.-E. S. E. throughout the mapped area, in conformity with that in Sambalpur to the west and north-west, and the Mahanadi valley to the south-east. A zone of faulting is noticed about two miles north-west of Kesaibahal (21° 55′ : 84° 24′) marked by a ridge made up of quartzite-breccia. There are, in the south-western part of sheet 73 C/6, a few linear zones parallel to the general strike, along which there has been intense lateritisation with concentration of limonite and manganese-ore. It is thought that these may be zones of shearing.

Bastar State, Eastern States Agency.

Dr. P. K. Ghosh continued his previous mapping, and completed portions of sheets 65 F/2 and 6. In addition he mapped parts of sheets 65 J/1 and 5 along the boundary between Bastar and Jeypore States.

In the first of these areas he states that the sequence is similar to that published in the General Report for 1936[1], except that the Kopayi quartzite is missing. He includes among his ferruginous and calcareous schists the hematite-quartzites and iron-ores of the Bailadila range, but he regards them as higher beds absent further to the east. His views in this matter differ somewhat from those of Dr. Crookshank, who regards the banded hematite-quartzites as belonging to a younger series separated from the older rocks by an unconformity. He agrees, however that there is an unconformity, but places it lower down, between his argillaceous and his quartzite series.

He notes the folding of the Bailadila range, and states that it has been accompanied by meridional faulting. The chief fault runs along the eastern flank of the range on sheet 65 F/2. Probably it is the continuation of the same fault that runs further south into the Tarali Metta (18° 32′ : 81° 15′). Parallel to this are several smaller thrusts at the foot of the range.

In the Jeypore-Bastar boundary region the Archæans are overlain by Cuddapahs, which are the continuation of the same formation in Bastar described in previous years.

[1] *Rec. Geol. Surv. Ind.*, 72, pp. 97-99 (1937).

The Archæan sediments are the same ferruginous and calcareous schists so commonly seen in Bastar. They include grünerite-schists and magnetite-quartzite, impure quartzites, and also calc-gneisses and charnockites. They have been injected by alkaline granitic rocks and by dolerites more or less similar to those seen in Bastar.

Dr. Ghosh states that field-evidence and microscopical features strongly suggest a genetic relationship between some of the charnockites and the calc-gneisses. In the field, the two rocks pass into each other, and the ferruginous schists and quartzites which occur with the calc-gneisses, show at such passage regions a higher degree of metamorphism than usual, and can also be traced from the calc-gneiss environment into a charnockitic one, the place of the calc-gneiss having been taken by the charnockite. The metamorphism of the calc-gneiss into charnockite is supposed to have been brought about by the agency of the alkaline granitic intrusive. The variation of the charnockite from the acidic to the basic end members is also noted and is explained as being due to the different degrees of acidification undergone by the original basic sediment (calc-gneiss) by interchange of material with the alkaline medium. While advocating this mode of origin for the charnockites in this particular area, he by no means suggests that similar rocks have not originated in diverse other ways, as suggested by previous workers in their respective areas.

Dr. B. C. Roy accompanied Dr. Crookshank in a short visit to the mineralized area south of Niwar in the Marwara *tahsil* of the Jubbulpore District. He has prepared sections of the ores collected, and has a note on them under preparation.

Bamra State, Eastern States Agency.

Subsequently he commenced field mapping in Bamra State, Eastern States Agency. He completed the mapping of sheet 73 C/5, which is partly in this State, and partly in the adjoining Sambalpur district. He also mapped small portions of sheets 73 C/1 and 9. The general geology of this area has been described by Dr. Krishnan (p. 77), but Dr. Roy has brought to light some interesting facts in the area which he has mapped. He shows that the quartzites of the Iron-ore series are often sillimanitic at their junction with the granitic gneisses. This probably indicates contact metamorphism of a rather high grade. At some of the junctions between these two rocks the sillimanite is apparently missing.

In such cases he has been able to show by his mapping that the junction is a straight line along which crush rocks of various kinds are well developed. He concludes that the sillimanite is missing in such exceptional junctions because the quartzites in these cases have never been in contact with the granite magma along them. The reasons why they now abut against the granitic gneisses are connected with faulting and denudation subsequent to the consolidation of the magma.

Nandgaon, Khairagarh, Chhuikhadan and Kawardha States, Eastern States Agency, and Drug district, Central Provinces.

Mr. Bhattacharji continued his previous years' work and mapped portions of Nandgaon, Khairagarh, Chhuikhadan, and Kawardha States, and the north-western portion of Drug district, C. P. The ground surveyed is included in sheets 64 C/14, 64 C/15, 64 F/4, 64 F/8, 64 G/1, 64 G/2, and 64 G/3. He also made a traverse from Borla (22° 10′: 81° 13′) to Chilpi (22° 10′: 81° 3′) and thence to Rengakhar (21° 58′: 80° 52′).

The rocks mapped by him included granitic gneisses, Sakolis and Cuddapahs, similar in most respects to those described by him in previous field seasons. The presence of limestone in the Sakolis is, however, a new discovery.

Drug district, C. P.

Mr. B. C. Gupta continued his work in Drug district, and completed the greater part of sheets 64 D/9 and 13.

The rocks mapped are the same as those described in the General Report for 1936[1] except that the oldest Archæan formation, the phyllitic schist. is absent. The most interesting feature of the area is a rock consisting of pebbles and boulders of quartz-porphyry in a fine-grained matrix of a similar composition. The boulders, which are very variable in size, are only found among the porphyries in the western part of the area mapped. Mr. Gupta considers them to be segregations, or perhaps inclusions of some sort. Their appearance, however, is very like that of boulders in a coarse conglomerate.

Ratnagiri district and Savantvadi State, Bombay.

Dr. L. A. N. Iyer was deputed to examine the mineral deposits of the Ratnagiri district and the Savantvadi State, Bombay Presidency, on sheets 47 H/11, 12, 15 and 16 and 48 E/9 and 13 on the one inch to one mile scale. Whilst engaged in this work, he took the opportunity to remap parts of that region.

[1] *Rec. Geol. Surv. Ind.*, 72, pp. 100-101 (1937).

The following are the geological formations in the area mapped by him :—

8. Alluvium.
7. Konkan laterite.
6. The Deccan trap.

Precambrian

5. Metamorphic rocks, basic.
4. Basic intrusions, dolerite, olivine-dolerite, olivine-gabbro, picrite and chromite-serpentine rocks.
3. Acid intrusions, biotite-granite-gneiss, biotite-hornblende-granite, porphyritic granite and pegmatite.
2. The Laladgi series (Cuddapah ?).
   - ii. Metamorphic phyllite, mica-schist, and biotite-granulites with garnet and hornblende.
   - i. Sedimentary sandstone conglomerate, micaceous sandstone and quartzite.
1. Dharwars ?, hematite-quartzite.

The Dharwars are represented in a few places by banded hematite-quartzites. The largest exposure is at Redi (15° 45′ : 73° 44′) where there is a long ridge of this rock largely altered to limonite.

Dr. Iyer states that the Kaladgis occur in two forms, unmetamorphosed and metamorphosed. The former comprise sandstones shales, conglomerates, and quartzites, the latter biotite-garnet-schists and biotite-granulites.

The unmetamorphosed types usually occur along the coast, or at the base of the great scarp here forming the eastern margin of the Konkan. Metamorphosed types due to contact metamorphism are found around granitic bosses midway between the scarp and the sea. The Vengurla *bandar* hill, where metamorphosed Kaladgis occur on the sea coast, is an exception.

Granites, pegmatites, and numerous intrusions, dolerites, gabbro and picrite, occur along with the sedimentaries. The ultra-basic intrusions have given rise to the chromite deposits of Kankauli and Vagda. The serpentine-chromite intrusions are generally found in association with hornblende-schist.

The latter is part of a group of basic metamorphic rocks which include hornblende-schists, amphibolites, and actinolite-schists.

The remainder of the area mapped is covered by Deccan trap, laterite, and alluvium. No features of new interest were noted in these formations.

The general structure of the area is an anticline with a slight pitch to the north. The granitic and metamorphic rocks are most commonly seen in the middle of the anticline. The unaltered Kaladgis and the overlying Deccan trap dip east and west away from the central axis. Due to the pitch the older rocks disappear beneath the Deccan trap in the north of the area mapped.

Hazaribagh district, Bihar.

During the latter part of the field-season 1937-38 (from March to April), Dr. L. A. N. Iyer started the mapping and investigation of the Bihar mica belt at the instance of the Bihar Government with special reference to the exhaustibility of the mica deposits. To obtain a first-hand idea of the problems relating to the mica mining industry, Dr. Iyer interviewed the representatives of most of the mining concerns near Kodarma. He also visited a number of mica mines during this period to obtain an intimate knowledge of mica mining.

In addition he also mapped during this period portions of standard sheets No. 72 H/10 and 11 on the scale of one inch to one mile.

The area forms the northern edge of the great batholith of 'Bengal gneiss', recently also called by Dr. Dunn the 'Chota Nagpur granite gneiss,' with its cover or roof denuded just deeply enough to expose the contacts and intrusive relations of the granite and pegmatite with the country rocks, this forming more or less a zone of hydrothermal and pneumatolytic reactions. The following are the geological formations of the area :—

6. Basic intrusions, metadolerite.
5. Pegmatite and graphic granite, tourmaline-pegmatite and mica-pegmatites.
4. Grnaite and granite-gneisses. Coarse-grained biotite-hornblende-granite, porphyritic granite and 'Rapakivi' granite.
3. Pyroxene-granulites.
2. Hornblende-schist.
1. Mica-schist and garnet-sillimanite-schist.

Dr. A. K. Dey continued the systematic geological survey of the Jashpur State, and mapped parts of the following sheets during the field-season 1937-38: 73 B/1, B/2, B/3; 64 N/13, N/14 and 64 M/S.E.

The geological sequence of the area examined is the same as that given for the adjoining region in the General Report for 1937.[1]

Jashpur State, Eastern States Agency.

The small exposures of grits, sandstones and shales in the area examined did not give sufficient evidence to decide whether their age is Lameta or Upper Gondwana. An interesting occurrence of grit containing small pebbles of agate, chalcedony, carnelian, etc., associated with the Deccan trap was found by Dr. Dey in the vicinity of Loro (23° 7′ : 83° 4′). These are at times good enough to be classed as semi-precious stones.

In the southern part of the State there are to be found deposits of auriferous gravel that were formed considerably earlier than the present-day alluvium. These deposits usually occur in the banks of the streams under the alluvium and consist of pebbles of quartz, granitic gneiss, tourmaline rock, etc. While it is impossible to assign any definite age to the gravels, the occurrence of laterite in them suggests that they were deposited some time after the formation of laterite from the Deccan trap.

Towards the latter part of the season, Dr. Dey undertook an investigation of the auriferous gravels of Jashpur. A brief summary of this work will be found under 'Gold' (p. 47).

BURMA GEOLOGICAL DEPARTMENT.

The Burma Geological Department, the successor of the Burma Circle of the Geological Survey of India, commenced to function as a separate entity on 1st April, 1937.

The present Burma Geological Department consists of the following officers on foreign service from the Geological Survey of India, which has agreed to provide officers to man the Burma Geological Department from April 1st, 1937, for a period of five years in the first instance.

Mr. E. L. G. Clegg, Superintending Geologist.

Mr. E. J. Bradshaw, Geologist.

Mr. A. B. Dutt, Assistant Geologist (Offg.).

[1] *Rec. Geol. Surv. Ind.*, 73, p. 104, (1938).

Mr. Clegg was on combined leave out of India for 5½ months with effect from 1st June 1937 and during this period Mr. Bradshaw officiated for him and combined the office work of the two posts of Superintending Geologist and Resident Geologist, Yenangyaung.

Library.

During the year 72 new volumes were acquired for the library: of these 63 were obtained by purchase and 9 by presentation.

Laboratory.

Mr. L. R. Sharma continued as Chemical Assistant throughout the year. During this period 65 specimens were reported on, out of which 29 were quantitatively determined. The specimens examined included a variety of rocks and minerals from the Katha, Toungoo, Yamethin, and Salween districts and the Shan States.

ECONOMIC ENQUIRIES.

Antimony.

Meiktila district.

Mr. A. B. Dutt reports the occurrence of stibnite in quartz reefs associated with shales and sandstones of the Coal Measures in the area about 1 to 1½ miles south by west of Lebyin (20° 40′ : 96° 29′), Meiktila district. The quality of the ore is good, an analysis showing 51·2 per cent. of antimony. An assay gave 0·06 oz. of silver per long ton of the ore. The deposit, according to Mr. Dutt, appears to be promising and well worth prospecting.

Barytes.

Anisakan, Mandalay-Maymyo Railway Line.

In March, 1937, Mr. Clegg visited a barytes deposit which occurs in crushed limestone rocks of Naungkangyi age, just south of the road from Anisakan to Taungyun and about 1½ miles from the former place. Anisakan lies on the edge of the Shan Plateau on the Mandalay-Maymyo railway line. About 160 tons of barytes had been quarried from the largest of a series of lenticles which

lie on a N. 27° W. strike and dip N. at about 60°. The mineral had been excavated down to a depth of 20 feet over a length of 30 feet.

Towards the north, where the exposure was opened up for another 30 feet, the lenticle breaks up into stringers of barytes in the impure ironstained and crushed limestones of the Naungkangyis.

A parallel series of smaller lenticles on the same strike occurs about 22 yards to the east of the open-cut. Other small outcrops of barytes were reported as occurring higher up the hill to the south and on the same strike east of Sakangyi to the north.

The area is certainly worthy of further prospecting and the main lenticle of further development, as there is a market for finely powdered barytes in Burma for the weighting of mud for circulation in the drilling of oil wells. The fineness requires to be below 300 mesh.

Copper.

Yamethin district.

Associated with diabase in the hill half a mile N. 5° E. of Paungdaw (20° 39′ : 96° 19′), Yamethin district, there is an occurrence of copper minerals such as chalcopyrite, chalcocite, malachite, azurite, etc. The occurrence, according to Mr. Dutt, appears to be of no economic importance.

Small patches of chalcopyrite were also noticed by Mr. A. B. Dutt in the calcareous quartzites associated with crystalline limestones one mile north-east of Paungdaw (20° 39′ : 96° 19′). This also is not likely to be of economic importance.

Granite.

Government quarries at Mokpalin.

In March, 1938, Mr. Clegg visited the Government stone quarries at Mokpalin to report if the reserves of granite and laterite available within working distance of the present jail site are sufficient to justify the erection of a permanent jail.

The quarries lie in an area specially reserved for Government quarrying in 1909. This area is covered by the 1″=1 mile Survey of India sheet 94 C/15 and lies to the east of the Pegu-Martaban railway line between miles 79 and 82 in an area of flat-topped hills

covered, where not cleared, by scrub jungle. The quarries are three in number and lie on or adjacent to the Mayan *chaung* in the southern part of the area. Three definite types of crystalline rock are quarried. In No. 3 quarry the rocks consist of a light-coloured slightly gneissic acid granite and a dark grey hornblende-lamprophyre (camptonite) consisting of idiomorphic phenocrysts of hornblende and occasionally of basic plagioclase felspar in a groundmass of small stocky crystals of basic plagioclase, hornblende and iron ore. Occasionally a little sphene is present. In Nos. 1 and 2 quarries practically none of the light-coloured acid granite is present and the rocks consist of the dark grey camptonite and a rather basic medium-grained hornblende-biotite-granite which approaches a diorite in composition.

The road-metal characteristics of these rocks vary considerably. The light-coloured acid granite breaks with an angular fracture; the abundant free quartz tends to cause dust and the rock as a whole lacks bonding properties. On the other hand the hornblende-lamprophyre is a tougher rock; it breaks with an angular fracture, is not inclined to splinter under load and possesses excellent bonding properties. The properties of the hornblende-biotite-granite will be intermediate between those of the other two.

The types of rocks described form the cores of the low flat-topped hills of the reserve; they are covered by a lateritised soil-cap of a variable thickness but generally of the order of forty feet on the tops of the hills, and less on the valley sides and in the beds of streams. Although the thickness of the hard laterite which is extracted for road-metal varies from a maximum of sixteen feet down occasionally to *nil*, it will invariably be found to be at least six feet thick beneath the hard capping of the flat-topped hills.

Detailed estimates within the immediate vicinity of the Jail camp showed that reserves of crystalline rock amounted to over 70 years supply at the maximum annual extraction rate or 290 years at the present production and that laterite sufficient for over a century exists within a radius of three-quarters of a mile of the camp. The amount of rock of each kind available in the reserve is for all practical purposes unlimited.

In 1937 a land-slide occurred in No. 1 quarry. The land-slide was due to a misguided attempt to prevent water from the slopes to the west from flowing into the quarry. A drainage channel had been sunk round the rim of the quarry set back just a

little from the edge. This drainage channel had prevented water from flowing over the edge into the quarry but unfortunately it had been the cause of seepage through the hard upper laterite into the lithomargic clayey bands below. These, becoming thoroughly water-soaked and lubricated, caused a land-slide of the harder upper laterite down into the quarry.

Gold.

Although jade mining is not being actively carried on in the Jade Mines district, in many places Mr. Clegg noted great activity in gold washing. Possibly gold washing has always been carried out by women concomitantly with the washing down of the Uyu boulder conglomerate in the search for jade boulders. In the Jade Mines area gold washing was either reported or noted as being carried out at the following places :—

Jade Mines district.

(1) *Mahok.*—East of the village in the stream which empties into Mamjan *chaung*. About 50 men were engaged in washing an alluvial flat.

(2) *Saingnaw.*—Washing was being carried out on the left bank of the Uyu *chaung* just below the junction with the Hwehka Hka. About 40 men were engaged, some in washing the sand on the stream edge and others in digging pits through the river boulder deposits and collecting for washing the sediments in which they were embedded.

(3) *Haungpa.*—Washing was being carried out on the banks of the stream which cuts through the village and then enters the Uyu *chaung*. Pits were dug in the Uyu boulder conglomerate and the sediments either washed in launders or pans, one pan of dirt giving a show of gold.

(4) *Uyu chaung.*—Along the Uyu *chaung* active washing was being carried out on sandbanks at the following places :—

(*a*) Three miles west of Pahok.

(*b*) On the island 1½ miles south-west of Nawnghena.

(*c*) Six miles west of Maingkaing.

(*d*) Sandbank south-west by west of Nwemannor.

(*e*) One and a half miles west by north of Nwemannor.

(*f*) Tonkhan opposite Malon.

Apart from the Haungpa basin, where there is a possibility of alluvial gold in the Uyu boulder conglomerate over a fairly extensive area, none of the other localities noted are of any importance. Those on the Uyu river below Haungpa are probably all due to resorting and concentration of gold from older gravels and sands weathered away during the rainy season.

The occurrences of gold in the Maingkaing area of the Uyu river and on the sandbanks of the Chindwin river have been previously reported on by Bion[1] who, after detailed examination, came to the conclusion that whilst the Kyobin deposit (Maingkaing area) was the best of the older gravels (Uyu boulder conglomerate), the payable gravel is so inconstant in character and intermixed with barren sand, that the ultimate return was far too low to enable large-scale work to be carried on at a profit. Further, Bion was of the opinion that the gold-bearing alluvium of the Chindwin can only be worked on the small scale at present adopted by the local inhabitants, who by years of experience are aware of the position of the richer pockets. With this opinion Mr. Clegg concurs.

Jade.

Jade Mines district.

In the Jade Mines district very little jade is being produced. The mines at Tawmaw have not been worked for some years and are flooded, whilst the village is deserted of all save the village headman and one or two local Chins. Very little working is being carried on in the sedimentary rocks, whether of Uyu conglomerate or earlier age, along the main stream. The reason for this cessation of industry is understood to be overproduction in the past, which has resulted in large stocks having accumulated in China, together with a decrease in demand owing to the Chinese war.

Lead-ore.

Yamethin district.

Mr. A. B. Dutt reports the occurrence of argentiferous galena in crystalline limestones associated with calcareous quartzites in the hills about one mile north-east of Payngdaw (20° 39′: 96° 19′), Yamethin

[1] *Rec. Geol. Surv. Ind.*, XLII, p. 241, (1913).

district. The lead-ore occurs as pockets, lenses, veins and stringers in the limestone. An analysis shows 64·51 per cent. of lead and 5·23 ozs. of silver per long ton of the ore.

This deposit was opened up by a company[1] in 1908 but after the extraction of 2,500 tons of ore in 1909 the mine was abandoned as " the supply of ore was exhausted ". Mr. Dutt is, however, of opinion that the deposit has fair possibilities and is worth further prospecting.

Mr. Dutt also notes that streaks of galena occur in light-greyish quartzites in the Myinzayan *taung* (△ 3573), 1¼ miles north-east of Chaungbya (20° 23′ : 96° 23′), Yamethin district. The galena is indefinite and occurs in small quantities and appears to be of little economic importance.

Natural Gas.

Yebawmi, Upper Chindwin district.

A series of natural gas and salt springs was noted by Mr. Clegg four miles north by west of Yebawmi (25° 17′ : 95° 45′) on the Uyu *chaung* in the Upper Chindwin district. The main gas spring occurs on the bank of a stream about twenty feet above the normal water-level. It is elliptical in shape with diameters of two feet and eighteen inches. The gas burns furiously ; the water through which the gas bubbles is greyish with mud and comes out of a hole about six inches in diameter in the centre of the pool, and down which a stick can be thrust for about six feet. A previous gas spring was also noted on a N. 30°E. bearing to the present pool and on this same line about 150 yards distant, occurs a series of salt springs through which gas also bubbles.

The rocks of the vicinity are bluish grey medium-grained massive sandstones ; they contain small quartz pebbles and are very Irrawaddian-like in character. They apparently dip to the south-east at 45° to the south and east and in a westerly direction to the north and west but the bedding is very difficult to make out owing to the massive nature of the sandstones and the poor exposures. Nevertheless there certainly appears to be an anticline on a north-east strike, faulted along the axis. Although Mr. Clegg was not able to get a sample of gas, there was no smell of petroleum in the

[1] *Rec. Geol. Surv. Ind.*, XLVI, p. 130, (1915).

vicinity and the gas is probably dry. In the gas springs from which brine is collected the water is clear but a considerable amount of iron is precipitated along the water channels.

Petroleum.

Mr. E. J. Bradshaw held charge of the office of Resident Geologist throughout 1937; he was consulted on technical matters arising out of the administration of the Oilfields and on problems relative to leasing and development. In addition he completed various confidential reports on oilfields practice for the Government:—

Railway Ballast and Road Metal.

Granite-porphyry, Meiktila district.

Mr. A. B. Dutt records that granite-porphyry is quarried in the hills east-south-east of Payangazu station (20° 45′: 96° 15′), Meiktila district, for use as road-metal and railway ballast. The rock is fine-grained, fairly compact and is sometimes associated with gneissic biotite-granite.

Granite-gneiss, Yamethin district, Burma.

Mr. Dutt notes that blocks of medium-grained granite gneiss occurring on the surface are broken to sizes suitable for use as road-metal and railway ballast in the hills north of Shwemyindin (△ 1134) (20° 27′; 96° 16′), Yamethin district. The material is transported to Yamethin, the nearest railway station, mainly by motor lorries during the fair weather.

Salt.

Yebawmi, Upper Chindwin district, Burma.

A small salt industry is carried out by a few local villagers at the gas and salt springs four miles north by west of Yebawmi (p. 89) and Mr. Clegg noted about twenty evaporating pans in action. Mr. Clegg was informed that the salt is sold in the villages along the Uyu river. The price received by the producers is four annas for five viss of salt, which is the production of one pan for a three days[1] boiling, a very poor return, rupees 50 per month for a community

[1] *Rec. Geol. Surv. Ind.* XLVI, p. 130 (1915).

of 14 or 15 people. An analysis of the salt gave the following results :—

	Per cent.
$Fe_2O_3+Al_2O_3$	0·20
$CaCl_2$	6·83
$MgCl_2$	3·17
NaCl	78·02
KCl	7·35
H_2O	5·60
Total	101·17

GEOLOGICAL SURVEYS.

During the 1937-38 field season Mr. Clegg carried out geological traverses in northern Burma in the following areas :—

(*a*) The First Defile of the Irrawaddy.
(*b*) The Jade Mines.
(*c*) Lai Sai State.
(*d*) The Uyu River.

In addition Mr. Clegg visited the Yenan test well of the Burmah Oil Company on the Yu River and the Indaw Oilfield of the Indo-Burma Petroleum Company.

Observations by Griesbach and Noetling.

Prior to Mr. Clegg's visit the geology of the First Defile was practically unknown. C. L. Griesbach[1] states that so far as it was possible to discover during the rapid traverses made by himself and Dr. Noetling, the entire area north of Bhamo appeared to be formed of a succession of flexures of older rocks, all striking more or less north and south to north-east to south-west, which flexures had been extensively eroded by the upper Irrawaddy drainage. He goes on to say that "Several larger synclinal troughs or rather areas of depression, have been formed when the beds composing the country north of Bhamo were compressed into folds; such, for instance, is probably the area of the Indawgyi lake basin and also the broad valley of the Irrawaddy between Hokat and Watu".

[1] *Rec. Geol. Surv. Ind.*, XXV, Pt. 3, p. 127, (1892).

Griesbach recognised the following formations:—

Formations recognised by Griesbach.

(1) Metamorphic, including probably the Palæozoic group.
(2) Mesozoic strata.
(3) Tertiary beds.
(4) Igneous rocks.

The only trace of Mesozoic rocks consisted of a pebble containing an ammonite, found by Dr. Noetling near the amber mines, which Griesbach and Noetling thought was probably of Cretaceous age and had been derived from a Tertiary conglomerate within the amber mines formation.

Noetling's Defile rocks shown as Silurian (?) crystalline limestone.

In the map which accompanies a paper by Noetling[1] on the occurrence of jadeite in Upper Burma, the whole of the First Defile is shown as Silurian (?) crystalline limestone. So too are the rocks which occur in the Second Defile below Bhamo.

Limestones of Second Defile of Cretaceous age.

As a result of an examination of the rocks of the Second Defile[2] and a traverse from Thabeitkyin across the Shweli basin to the Second Defile, Mr. Clegg had been unable to discover any trace of Palæozoic rocks, whilst the limestones of the Second Defile, which continue across Mongmit State to the south-west, had turned out to be of Cretaceous age. It seemed extremely probable therefore that the rocks of the First Defile and also of the Jade Mines area would also be of Cretaceous age and Mr. Clegg's field work during part of the 1937-38 field season was planned to settle the question.

(*a*) The First Defile of the Irrawaddy lies between Sinbo (24° 47′; 97° 3′) at the north end and Thapanbin (24° 21′; 97° 8′) at the south.

First Defile not a true defile but a narrows.

In the strictest sense of the word it is not a defile at all, but a 'narrows'. Nowhere down the whole 40 miles of narrow river are cliffs to be seen of more than 60 feet in height. Nevertheless it is a beautiful natural feature, as the mountains rise up on either side to over 3,000 feet; their slopes are forest covered and were it not for the occasional *taungyas* on the heights, might tend to monotony as the forest,—literally impenetrable—comes right down to the river banks.

[1] *Rec. Geol. Surv. Ind.*, XXVI, p. 26, (1893).
[2] *Ibid.*, 71, p. 350, (1937).

Course of Irrawaddy north of First Defile.

Northwards from Sinbo to the confluence of the Mali Hka and Nmai Hka, its two main sources, which bound the wild tract of the 'Triangle' above Myitkyina, the Irrawaddy describes a series of big meanders, mostly through recent alluvium, although occasionally isolated forested hills and ranges flank the banks. At Sinbo the river is about 1,000 yards wide and sandbanks split up the main stream during the low-water season into a number of distributaries. These merge two miles below Sinbo to flow in a swirling, swift-flowing river through the heart of a serpentine intrusion which has been weathered and carved into dark statuesque rocks and pinnacles. The river widens a little on leaving the serpentine in its passage through a series of volcanic ashes and lavas and then becomes wider still and more quiescent as it flows practically along the strike of compressed shales and calcareous grits past Nanhe, to narrow once again at Kokma, where the same rocks are indurated by plutonic and hypabyssal intrusions. It is here, one mile below Kokma, that the river narrows to its minimum width,—about 60-70 yards—where a mass of altered sediments penetrated by anastomosing igneous veins crosses the river and forms a narrow gate through rocks which rise about 60 feet above the low-water level of the river. At one time a pagoda crowned a mass of dolerite on the left bank of the river just below the gate, but was swept away during an abnormal rise.

Minimum width of river at 'Pashaw' below Kokma.

Below the gate, which is known as the 'Pashaw,' the main stream of the river is flanked in times of flood by two large whirlpools and the swirling waters are not navigable then either for mechanically propelled boats or country craft. Even during the low-water season the passage of this section of the river is somewhat disturbing to inexperienced travellers in dug-outs, owing to the small eddies and swirls which occur and the manner in which an eddy will suddenly 'break' close to the boat.

First Defile not navigable in times of flood.

For about a mile below the 'Pashaw' until the Myitkyina-Bhamo boundary is reached, the river flows swiftly and the banks, composed of serpentine and rocks of volcanic origin, are very much indented; minor promontories protect little sandy bays where the local inhabitants leave their canoes whilst working in the *taungyas* on the hill slopes high above.

From just above Letma (24° 38′; 97° 7′) to Htonbo (24° 30′; 97° 7′) the rocks are all of a sedimentary nature; they consist of calcareous grits and shales all very much crushed and cleaved; in them Cretaceous foraminiferal limestones frequently occur. East of Namti (20° 34′; 97° 7′) and close to Htonbo there are limestone cliffs; they do not, however, form outstanding physical features, as do the limestones of the Second Defile. East of Namti (20° 34′; 97° 7′) limestone cliffs, which occur less than a mile from the eastern bank, cannot be seen from the river at all, so clothed are they by forest growth, and yet they are from 200-300 feet high and contain at least one large cave, now, notwithstanding the bats, transformed into a place of worship by the local Burmese Shans. At Htonbo the limestones are seen as low greyish white cliffs (40 feet) veined with calcite. Between Lawngpu and Namti the rocks dip fairly regularly at high angles to the west; the softer bands have been denuded away and razor-backed islands and rocks fringe the eastern bank, which rises steeply from the shore to the high peak of Loi Manaw (1801) just over a mile away. To the west the peak of Loi Hpun (3382) with its high *taungya*-covered slopes, is the dominating peak of the ridge formed by the serpentine and volcanic rocks mentioned as occurring below the 'Pashaw' or 'gate.'

Cretaceous sediments; Letma to Htonbo.

Below Htonbo the river makes a big bend to the east and then swings through a semicircle to flow south-west past the village of Thamainggyi (Thabyebin on the map, 24° 28′; 97° 8′). The rocks seen on the east-west reach strike north by east and consist of volcanic lavas, ashes and tuffs and, as the river cuts across their strike, provides probably the prettiest section of the defile. Isolated rocks and small tree-covered islets break up the river into a lake-like expanse of water, and dug-out canoes can pass along narrow channels on the right bank unseen from the main river.

Volcanic and ashy rocks of E.-W. reach below Htonbo.

Where the river swings to the south again below Thabyebin, intrusive diorite rock crops out and is responsible for the pagoda-crowned promontory known as 'Rob Roy' rock.

South end of defile made up mostly of igneous rocks.

Southwards to the lower end of the defile the rocks are practically all of a volcanic nature; the scenery becomes featureless as the mountain slopes become more gradual, before finally at Thapanbin giving place to the flat alluvial plains of the Bhamo basin, where

the river widens and passes through a maze of sandbanks to the town.

(*b*) The Jade Mines area was geologically surveyed by Dr. H. L. Chhibber[1] during the 1928 and 1928-29 field seasons. In the course of his survey Chhibber recognised the following divisions :—

Jade Mines area.

(1) Alluvium.
(2) Volcanic rocks.
(3) Uru boulder conglomerate.
(4) Granodiorite.
(5) Crystalline complex.
(6) Tertiaries.
(7) Peridotites and serpentines.
(8) Limestones.

In the limestone Chhibber reported the occurrence of *Fusulina elongata*, *Fenestella*, *Textularia* and various forms of *Globigerinidae* and inferred from this that the limestone was of Permo-Carboniferous age.

In the course of Mr. Clegg's traverse he visited the following areas from which Chhibber collected limestones :—

(i) On the Hkakan Hka three-quarters of a mile west of bridge 22/1 on the Mogaung-Kamaing Road.
(ii) The Uru Hka north of Kansi.
(iii) Junction of the Nammon Kha and Hwehka Kha.

Limestones west of bridge 22:1 on the Mogaung-Kamaing road.

(i) The limestone of the Hkakan Hka is dark-bluish grey in colour, very crushed and veined with calcite. It breaks with a fetid odour and appears to dip north-north west at 30°. In thin section traces of *Orbitolina* and other foraminifera were noted. Folded up against the limestones in the higher of the two exposures are cleaved shales similar to the Cretaceous shales of the defiles. The base of the limestone is not exposed. On the Hkakan Hka east of the limestones, serpentine is exposed in the stream-bed.

(ii) The limestone of the Uru Hka north of Kansi consists of white crystalline limestone. On the left bank, where the stream narrows,

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 108, (1929); LXIII, p. 97, (1930).

marble cliffs one hundred feet high occur. Some of the marble is pellucid and might make a good building stone, although on the whole the rock is not very homogeneous and boulders were found containing rhombs of calcite up to half an inch long, besides patches of calcite of a saccharoidal type. Mr. Clegg could not make out any true bedding on the western side of the occurrence, though it is probable that this mass of limestone has an easterly dip. The rock is completely crystalline and there is no trace of any organic structure. Debris in the stream consists of diorite-gneiss, peridotite and hornblende-schists and could not have been derived from any great distance.

The Uru Kha north of Kansi.

(iii) From the junction to one furlong to the west-south-west of the Nammon Hka and the Hwehka Hka fossiliferous limestone containing *Orbitolina birmanica* occurs. The limestone is of a greyish colour and is very much veined with calcite. Further to the west-south-west serpentine later than the limestone occurs. The contact rocks are all very silicified.

The Nammon Hka-Hwehka Kha Junction.

Although the limestone exposures at the junction of the Hwehka Hka and Nammon Hka and three-quarters of a mile west of bridge 22/1 on the Mogaung-Kamaing Road were the only two exposures in the Jade Mines area proper where Mr. Clegg was able to trace Cretaceous fossil remains, there is no question that the more metamorphosed limestones belong to the same series and that their age is Cretaceous.

In his progress report for 1927-28 (page 27) Dr. Chhibber, in describing Tertiary sandstones, shales and conglomerates, mentions that some of the best sections of these rocks are to be found in the south along the Hwehka Hka between Hwehka (25° 29′; 96° 17′) and Mawkalon (25° 30′; 96° 18′). A particular specimen obtained from one mile north-north-east of Pt. 981 in the Hwehka Hka (sheet 92 C/6) was a black carbonaceous limestone in thin sections of which foraminifera resembling *Patellina* were distinguished by Chhibber. It seems very likely that this black carbonaceous limestone is part of the Cretaceous system and that the specimens described as *Patellina* belong to the *Orbitolinae.*

(*c*) From Haungpa (25° 30′; 96° 6′) it was Mr. Clegg's intention to traverse in a north-north-easterly direction to Hsingaling Hkamti

on the Chindwin river. In this he was disappointed owing to the tract being unfit for mule transport. Nevertheless he was able to progress sufficiently far into Lai Sai State to encounter Cretaceous rocks. Limestones of this series are exposed in Hpalamung Bum, which rises sheer from the Hpalamung fields to a relative height of 900 feet and an actual elevation of 1,643 feet. The limestone is of a fawn colour and contains *Orbitolinae* but they are not at all common. The limestone at the foot of the precipice on the south side of the ridge is weathered into pinnacles similar to those seen in areas of sub-surface weathering of limestones. To the north-west of Hpalamung Bum other similar limestone ridges occur *en échelon* with it, whilst on the stream south-west of Pt. 1648, calcareous sandstones and shales dip south-west by west at 65°. The latter are very similar lithologically to the series found in association with Cretaceous limestones in the First Defile of the Irrawaddy.

Cretaceous rocks of Lai Sai State.

To the west and north-west of the limestone ridges basaltic lavas and various medium and coarse ashes and tuffs occur, whilst from the map contours shown on the right bank of the Nam Tonthun twelve miles to the north-west of Hpalamung Bum, limestone peaks again appear to crop out.

(*d*) South of Haungpa the high range of the Sinhku Bum throws out spurs in a westerly direction to the Uyu river. These spurs were found to be composed 2½ miles south-south-west of Haungpa of a garnetiferous micaceous gneiss consisting of a little quartz, felspar, muscovite, garnet and kyanite and ten miles south-south-west of Haungpa of quartz, actinolite, graphite, and a little muscovite. This crystalline schistose series continues to the north into the Jade Mines area and is probably of Cretaceous age.

The Uyu river below Haungpa.

Southwards down the Uyu river from Shwedwin, only Tertiary rocks overlain by the Uyu boulder conglomerates are visible. The Tertiary sandstones are mostly massive and fawn in colour though some bands are blue, rather shaly and weather spheroidally into fine needle shapes. Occasionally conglomerates and gravel patches occur in the sandstones, whilst concretionary calcareous lenses are common. At times the sandstones are false-bedded and at others soft and porous and from cliff sections of the latter chalybeate waters

seep. Towards the Maingkaing basin gravelly beds become more common as also do ferruginous concretions. Dips are very hard to determine along the river and especially so in the cliff sections which rise to heights of 70 feet above the water-level. Nevertheless from Yebawmi to the south-west there is a prevailing dip of these Tertiary sandstones to the south-east by south.

The Uyu conglomerate forms terraces at different elevations, two high-level terraces being visible at Yebawmi. The upper village is situated on the higher one about a hundred feet above the level of the river whilst the village monastery is on the lower, about twenty feet below. Opposite to Yebawmi the conglomerate has apparently a very wide extent.

Meiktila and Yamethin district.

109. Mr. A. B. Dutt worked in parts of the Meiktila and Yamethin districts in the eastern half of sheet 93 D/2 and 6 and the north-eastern quadrant of sheet 93 D/3 and 7. The geological formations mapped by Mr. Dutt were as follows :—

(1) Plateau Limestone.

(2) The Kalaw coal measures, and their metamorphosed equivalents.

(3) Granite and associated rocks.

(4) Alluvium.

(1) *Plateau Limestone.*—The oldest formation of the area, the Plateau Limestone, crops out at the north-eastern corner of sheet 93 D/2 and 6 and consists of grey massive limestone, much brecciated and traversed by innumerable veins of calcite, mostly white. No fossils were found in it.

(2) *The Kalaw coal measures.*—Overlying the Plateau Limestones and by far the most predominant rocks of the area are the Kalaw coal measures; they occupy a third of sheet 93 D/2 and 6 and the major portion of the eastern half of sheet 93 D/3 and 7 and consist of shales, sandstones, grits and arkose, conglomerates, phyllites, mica-schists, quartzites, limestones, calciphyres, calc-granulites, etc., etc. The shales are of a greyish to buff yellow colour whilst the sandstones and shaly sandstones vary greatly in colour from buff to greyish white. The sandstones are often fine-grained, though occasionally gritty varieties may be noticed, as for instance, about one mile north-east of Mindale (20° 34′; 96° 21′). Besides normal

pinkish conglomerates metamorphosed conglomerates were encountered. Greenish to grey slates, greyish and brownish phyllites and brownish mica-schists are found at the junction of the coal measures with the granites intruded into them. Thin-bedded light to dark grey limestones and occasionally massive saccharoidal limestones apparently overlie the metamorphosed sediments mentioned above as they occur on the western flank of the coal measures outcrop. Some of these limestones are altered to marbles, calciphyres and calc-granulites and contain calc-silicate minerals such as tremolite, diopside, epidote and zoisite. In the hill east and north-east of Pyinbya (20° 26½′ ; 96° 18′) the metamorphosed limestones contain garnet (grossularite) in abundance.

The rocks are folded into anticlines and synclines on a general N. N. W.-S. S. E. strike.

Last season a small triangular outcrop of metamorphosed rocks was mapped by Mr. Dutt west of Yinmabin station (20° 46′ ; 96° 22′) at the south end of sheet 93 D/1 and 5. The exact correlation of these rocks was not possible at that time; but mapping to the south has now shown that these metamorphosed sediments pass along the general strike to unmetamorphosed shales and shaly sandstones of the Kalaw coal measures series, and owe their metamorphism, at least in part, to the intrusion of a granitic magma.

(3) *Granite intrusions and associated rocks.*—Intrusive into the coal measures are granites and associated diorites, which have metamorphosed the sedimentary series in their vicinity. The granites are generally biotitic and often gneissic, whilst shearing is noticeable in the coarser types. Porphyritic varieties occasionally occur. The granites are traversed by quartz veins and pegmatites, whilst dark basic segregations are sometimes seen. Muscovite-granites are by no means rare and are found in the hills west of Naungkhwin (20° 36′ ; 96° 17½′). With an increase of hornblende the granites grade into hornblende-granites and diorites. One diorite outcrop, having an area of about two square miles, was noted in the vicinity of Kywegya (20° 42′ ; 96° 16′). Small lenses of porphyries and aplites are also found intrusive into the coal measures.

(4) *Alluvium.*—The alluvium is either greyish or light brownish in colour and consists of a fine clayey soil, which when moistened with water, becomes slightly plastic. The alluvium forms fertile land in which rice, cereals, beans, etc., are grown in abundance.

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THE STRUCTURE OF THE SHALI 'WINDOW' NEAR SIMLA. BY W. D. WEST, M.A. (CANTAB), F.N.I., *Geologist, Geological Survey of India.* (With Plates 1 to 6.)

CONTENTS.

1. INTRODUCTION.

H. B. Medlicott.

The foundations of our knowledge of the geology of this area were laid by H. B. Medlicott in his memoir "On the Geological structure and relations of the Southern portions of the Himalayan range between the rivers Ganges and Ravee", published in 1864.[1] In that work the Shali area provided him with a problem of peculiar difficulty, in that less metamorphosed rocks appeared to dip in all directions beneath more metamorphosed rocks. Although Medlicott was unable to solve the problem himself, his observations on the geology were so acute, and his recognition of the difficulties to be solved so clear, that it was possible, after reading his description, and with a knowledge of the neighbouring area, to see the probable solution in advance, a solution that has since been confirmed.

Medlicott covered the amazing area of 7,000 square miles in two seasons, striding like a giant through the land. Had he been

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 2, (1864).

able to examine the geology in greater detail, it is possible that he would finally have come to a satisfactory understanding of the structure, though the theory of *nappes*, and the horizontal movement of large rock masses that they imply, had not then been elaborated. As it was, he was compelled to leave the problem unsolved.

H. H. Hayden.

Subsequent to Medlicott's work, no geologist seems to have visited the area until the late Sir Henry Hayden came to Simla as Director. On at least three occasions during this period he spent seven or eight days in camp on the southern slopes of Nag Tikar, a peak north-east of Shali. The chief interest of these visits lay in his discovery of Nummulitic beds on the southern slopes of the Shali range, a position unexpectedly far into the Himalaya for beds of this age. This discovery was reported in the General Reports for the years 1918 and 1919.[1]

R. W. Palmer.

As a consequence of Hayden's discovery, in the summer of 1920 the late Capt. R. W. Palmer was deputed to survey the area in detail, and spent about six weeks on either side of the Nauti *khad*. He subsequently submitted a short Progress Report, which was accompanied by a map of part of the area on the scale of two inches to one mile. On this map Palmer showed a number of small outcrops of Subathu beds, and he subdivided the rocks into various groups :— Shali limestone, Shali quartzite (a stage that he subsequently abandoned), Madhan slates, Subathu beds, and the curiously named Mule Track series (subsequently identified by Pilgrim and West as their Chail series), in order of superposition upwards. In his report he discusses the age of the Mule Track series, and their apparently anomalous position above less metamorphosed beds, and concludes that they are either Tertiary in age or that they owe their present position to thrusting. In the summary of his work in the General Report for the year 1920 there occurs the following statement[2] :—

"The relationship between the Madhan slates and the overlying limestone and slate series has not yet been established. The latter, from its position, looks as if it must coincide with Mr. R. D. Oldham's 'Infra-Blaini beds or Simla slates'.

[1] *Rec. Geol. Surv. Ind.*, L, pp. 8-9 (1919); and *op. cit.*, LI, p. 9, (1920).
[2] *Op. cit.*, LIII, pp. 10-11, (1921).

The passage from the Madhan slates into these overlying beds showed no physical discordance, but conformability between the two would necessitate a revolution in our ideas of Simla geology, making the rocks around Simla itself Tertiary in age. The alternative view is that the boundary between the two series is a discordant one—a thrust fault in fact of considerable magnitude, warped perhaps by subsequent movement."

In 1927, Dr. G. E. Pilgrim, in the course of a joint survey in association with the present writer, spent a few days in this area.

G. E. Pilgrim.

Pilgrim identified Palmer's Mule Track series as being Lower Chails (Purana), and concluded therefore that the base of this series was a thrust in order to account for the superposition of Purana rocks on Subathu (Tertiary) beds. Pilgrim also found further outcrops of Subathu beds to the west of those discovered by Hayden and Palmer, on the south-west slopes of the Shali ridge. His modification and extension of Palmer's map was included in the map published with our joint memoir.[1] Based as it was on a visit of a few days only, it could only be regarded as of a reconnaissance nature, though his experience of other parts of the Simla hills enabled him to understand certain problems which Palmer had, perforce, to leave unsolved. Neither Pilgrim nor Palmer, however, really appreciated the full complexity of the structure of this area, an understanding of which has only been obtained by detailed mapping on the scale of two inches to one mile.

Topography.

The dominant features of the topography of this area are: (1) the Shali ridge, a branch spur running W. S. W. from the main Narkanda—Fagu ridge (the watershed between the Sutlej and Ganges drainage systems); and (2) the Sutlej river, flowing rather south of west, north of the Shali ridge. A less important but still well marked feature is the Nauti *khad*,[2] which bounds the Shali ridge on its south side, and separates it from the Narkanda—Fagu ridge, joining the Sutlej at Chaba. North of the Sutlej the ground rises steadily up through Suket State to the main granite ridge of Mandi State and Kulu, which is a spur running W. S. W. from the Great Himalaya Range, and reaches heights of 11,000 feet.

[1] *Mem. Geol. Surv. Ind.*, LIII, (1928).

[2] The term *khad* is used in this paper in its local sense, meaning a valley or the stream at the bottom of a valley. In the latter sense the terms *khala* and *gad* are also sometimes used, as in Mangled Khala and Chairro Gad.

The main features of the topography are shown in the following sketch map :—

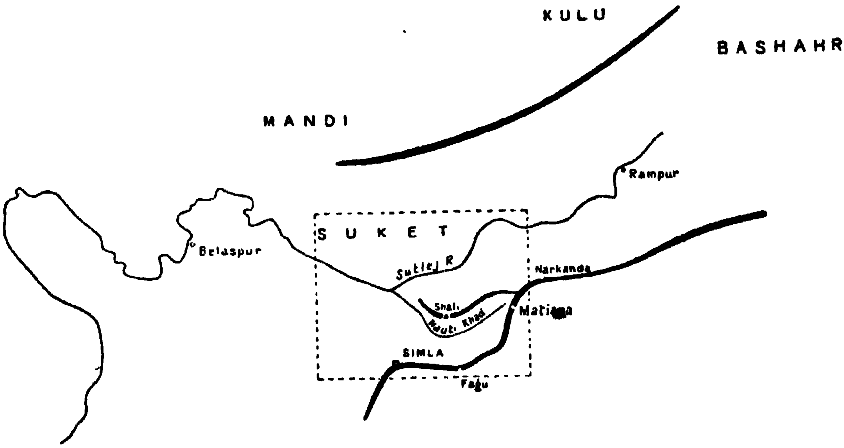


FIG. 1.—The main topographical features of the area, scale, 1″=24 miles.

The area described in this paper is shown within the dotted lines.

The topography of the Shali area is one of great relief. The summit of the Shali is 9,406 feet high. To the north of it, at a distance of only five miles, the Sutlej river flows at 2,300 feet, while to the south of it is the Nauti *khad* at about 4,400 feet.

The Shali peak forms a prominent feature in the middle distance in the view north-east from Simla. To anyone familiar only with this view of the mountain, a bare dip-slope of massive limestone, it would probably come as a surprise to learn that the northern slopes are thickly covered with a dense forest of deodar, oak and pine. This, however, is a common feature of Himalayan ridges aligned in an E.-W. direction, due to the northern slopes retaining the snow and moisture for a longer period than the southern slopes, and thus affording the vegetation more favourable conditions for growth. Medlicott has described the area north of the Shali as follows :—

"Massive bands of limestone are tossed about in every direction, the crumpled slate rocks have yielded easily to denuding forces ; thus producing a combination of deep narrow gorges and of lofty rock cliffs, which are densely covered with forest on every available spot."

Of the plates accompanying this paper, Plate 1 shows the whole Shali range viewed from the south, and is taken from Wildflower Hall, six miles east of Simla. On the far side of the range comes the Sutlej valley, while in the foreground is the Nauti *khad*.

The area dealt with in this paper is covered by the one-inch sheets 53 E/3, E/4, E/7, and E/8. The actual mapping, however, has been done on the old two-inch sheets 310 S. W. and S. E., and 311 N. W. and N. E. These two-inch sheets, though old, are for the most part remarkably accurate, and often more accurate and reliable than the much later one-inch sheets. Plate 5 of this paper is a somewhat simplified map of the whole area on the scale of one-inch to two miles. In it the Tertiary beds and the Madhan slates have been grouped together under one colour, while the Upper Shali limestone and the Shali quartzite are also shown under one colour. Plates 6 is a reproduction of the most complicated portion of the two-inch sheet 311 N. E., and covers the area in which the structures beneath the Shali thrust are best displayed, and in which the Tertiary beds are most fully developed. The spelling of the place-names on the two maps is often different, and where necessary both forms are given in the text.

2. THE SUCCESSION.

It is not proposed in this place to describe the lithology of the various rock groups in any detail. A brief description is, however, necessary, before describing the structure of the area.

The rocks of the area can be subdivided as follows:—

TERTIARY—	
Dagshai beds . . .	Purple shales, with interbedded purple and green sandstones.
Subathu beds . . .	Jointed shales, with thin beds of limestone containing nummulites.
MADHAN SLATES . . .	Rusty brown sandy slates, finely jointed, and slightly micaceous.
SHALI SERIES—	
Shali quartzite . .	Pure white quartzite, sometimes containing chert.
Upper Shali limestone .	Massive, grey, dolomitic limestone, full of parallel sheets of chert.
Shali slates . . .	A variety of slates and slaty limestones.
Lower Shali limestone .	2. Massive, grey, dolomitic limestone, with only occasional chert.
	1. Pink calcitic limestone with no chert, banded at the base.
Khaira quartzites . .	White and purple quartzites.
CHAIL SERIES . . .	Dark silky slates and phyllites, with interbedded dark calcitic limestone, frequently banded.

With the exception of the Subathu beds, which contain nummulites and are of Laki age, none of the above series contains any fossils, and their age is unknown. It is generally assumed that the Chail series are Purana in age, and recent work suggests that they are probably equivalent to the Simla slates, of which they may be a more highly metamorphosed facies. It also seems probable that

the Shali series are homotaxial with the Krol series, but there is still some doubt in the matter.

3. THE STRUCTURE IN OUTLINE.

The outstanding feature of the structure of this area, and the one that gives to it such absorbing interest, is the Shali thrust. The trace of this thrust describes more than three-quarters of a circle, and is conveniently shown by a red line on the half-inch map forming Plate 5 of this paper. Within the area bounded by the thrust the general structure is that of a dome, with the rocks dipping outwards in all directions, as shown in the following sketch-map, which gives the course of the thrust and the dip of the rocks beneath it.

The Shali thrust.

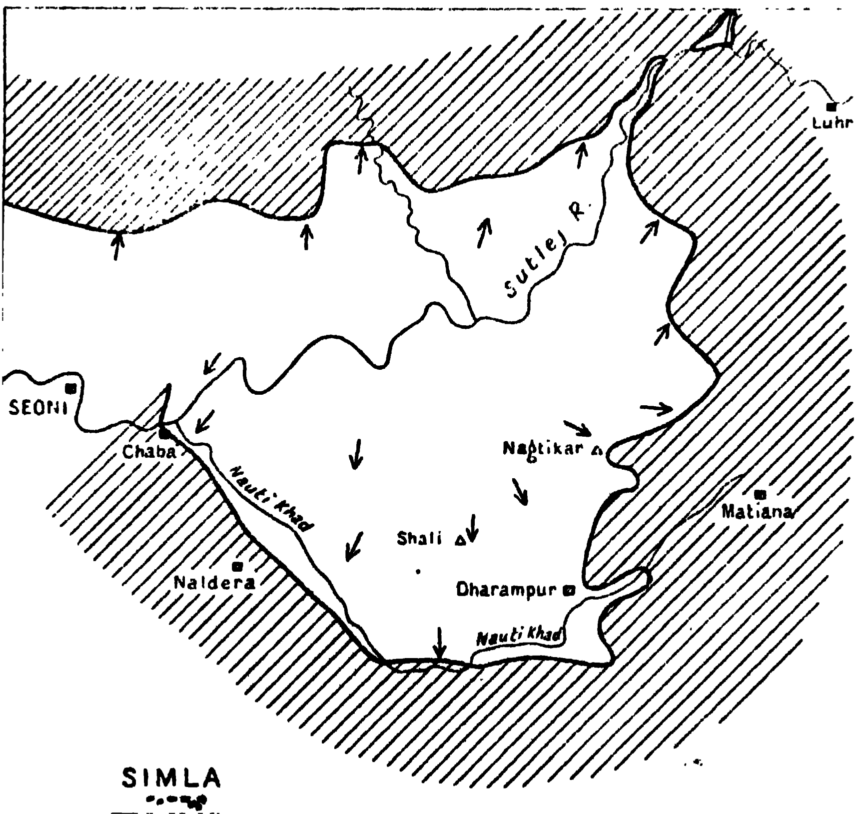


FIG. 2.—The dip of the rocks within the 'window'. Scale 1 inch=18 miles.

The centre of this dome is not the Shali peak, but some distance north of it, in fact over the Sutlej valley where the lowest beds appear. This divergence of dip is well shown by the Upper Shali limestone along the Shali ridge. At the Shali peak the dip is due south; further east by Nag Tikar it is almost due east; while to the west, by Chaba, the same rocks are dipping south-west. The gradual change in dip is shown best of all by the overlying Chail series, which throughout display a very regular disposition, as of a gently warped sheet. At Chaba the dip is south-west; below Mashobra it is south; by Nag Tikar it is east; by Kangar it is north-east; where it crosses the Sutlej it is north-north-east; while westwards from here it becomes due north and continues thus for a long way. Though I have described the general structure as a dome, this is not strictly correct, since the western end remains open. Nor can it quite be described as an anticline, pitching eastwards. It is really an anticline with the eastern end dome-like.

The dome-like disposition of the strata.

Medlicott fully appreciated this steady divergence of dip, and recognised the difficulty of accounting for the centre of the dome being occupied by what he judged to be the youngest rocks according to their grade of metamorphism. It is worth while in this connection making two quotations from his memoir. On page 49 he writes:—

"In going from Shali to the south, to the east, or to the north, we find the same rocks have assumed a steadily diverging dip".

Further on, on page 51, he writes:—

"Here we have a three sided divergence of dip in what seems to be a band of special depression....How (keeping in mind the magnitude of the section) these limestones of Shali became so deeply let into this inverted trough of older strata, is more than I can at present explain. If the east end of this trough were an ordinary fault, or a rapid elevation and truncation of the calcareous strata, the case were comparatively simple; but it is not so; the abnormal superposition of the older strata is as regular on the east as on the north".

For an explanation he is forced to fall back upon the possibility of its being some kind of fan structure, an explanation which he rejects; or that it is an example of the deposition of younger rocks against a steep cliff of older rocks, a favourite explanation of his in

Medlicott unable to solve the structure.

the case of the inversion of strata in the Tertiary rocks of the outer Himalaya. Since, however, this would involve a very extensive unconformity of the two series, he rejects this explanation also, and is forced to leave the problem unsolved.

Recognition of the Shali thrust provides a solution.

The detailed mapping of the past few years has now supplied an answer to the problem. The rocks above the Shali thrust belong to the Chail series, presumed to be Purana in age. Those below the thrust are a mixed assemblage consisting of the Shali series, the Madhan slates, and Subathu and Dagshai beds of Tertiary age. As a result of nearly horizontal movement, the Chail series have been forced many miles to the south-west over strata that are younger in age, so as to overlie them as a flat sheet. Subsequent denudation has worn away this covering of older rocks in the Shali area, and in the "window" thus opened we can see the younger rocks beneath. Thus, before the denudation of the Sutlej and the Nauti valleys, the Chail series must once have extended, right over what is now the Shali range, as a flat though slightly warped sheet. The evidence for the truth of this explanation will be given in the succeeding sections of this paper.

4. THE SHALI THRUST.

In describing the Shali thrust, and the evidence for its existence, we may conveniently begin in the vicinity of Alsindi in Suket State, north of the Sutlej, and follow it eastwards from here right round the nearly complete circle that it describes, noting all along the nature of the junction between the Chail series and the underlying rocks, and the nature of these underlying rocks themselves.

Alsindi.

At and around Alsindi the Shali limestone is seen in full force. Both the pink, thin-bedded, calcitic limestone forming the lowest part of the Lower Shali limestone, and also the massive grey dolomitic limestone that comes above it, are well displayed, striking nearly east and west, Alsindi itself being situated on the former.

Proceeding northwards from Alsindi along the main road, an interesting section is seen where the road bends round sharply to

the north, opposite Gad. At this point the road rests on massive grey Lower Shali limestone. Above the road, for about 100 feet, beds of the finely banded Chail limestone are well-displayed, dipping north. The road itself comes exactly at the junction of the Chail and Shali series, and there is definite evidence of crushing in the basal few inches of the Chails, while the top of the Shali limestone is for a few inches rolled out into a mylonite, finely laminated and platy.

Further east for a long way the section remains much the same. *In this part of our area, therefore, the Chail series rests directly upon the Lower Shali limestone.*

Further east, crossing the Chainre Gad, the boundary swings north in accordance with the northerly dip. Where it runs south-east again on the east side of the valley the junction is clearly visible from a distance, for the massive Shali limestone, with its precipitous scarp slopes, shows up in striking contrast to the overlying softer Chail rocks, with their more subdued topography.

Incoming of the Shali slates.

It is along here that an important change occurs at the boundary of the two series. At about longitude 77° 16¾′ the Shali slates suddenly come in between the Chail series and the Lower Shali limestone, and rapidly attain almost their full development. Although it is difficult to point to any visible discordance at the junction, nevertheless the strike of the slates as a whole soon after they appear, west of Ropra, is slightly oblique to the strike of the overlying Chails. These latter here include a bed of quartzite at their base; and whereas before the slates appear this quartzite rests directly on the Lower Shali limestone, after the slates have appeared the same bed of quartzite rests upon these slates. The Shali slates here are very similar to the Shali slates that are seen on the northern slopes of the Shali range, and are typically dull black splintery slates, bleaching to a light grey colour, and passing downwards into a banded slaty limestone, and upwards into earthy thin-bedded limestones. This horizon is well displayed on the ridge running north from ·6871, and in the valley to the east by the villages of Koti, Kader and Baran.

Before leaving this part of the area, I may refer to an important distinction between the rocks of the Shali slate band and those

of the Chail series. The general grade of metamorphism exhibited by these two groups is quite different. The Shali slates are partly simple clay slates, with little or no metamorphism, or true slates with a cleavage, but still lacking in signs of further metamorphism; whereas the overlying Chail rocks are phyllites or silky schistose slates which have clearly already undergone preliminary recrystallisation of 'epi' grade. In addition to this distinction, the Chail phyllites differ from the underlying rocks in being full of vein quartz, whereas in the rocks below the boundary there is not a sign of vein quartz. This distinction is seen throughout the area, irrespective of the nature of the underlying rocks, and its importance will be discussed more fully below.

Difference in metamorphic grade above and below the thrust.

The next important change to occur along the boundary that we are following is seen to some extent by the Sutlej river north of Tundal, but is most strikingly displayed further south-east, by Kot and Chajahi in the Pandoa *khad*, and will be described in the latter place first. The boundary representing the base of the Chail series pursues a very regular course below Tha, Thanu, Chajahi and Odar, the dip changing slowly from about N. 30°E. by Tha to north-east by Chajahi and Odar. This is but a part of the gradual swinging round in the strike of the area at the north-east end of our dome, already described. But if, instead of following the base of the Chails, we follow the top of the Lower Shali limestone, by Ghogoi, Thanena and Kot, we find that whereas from Ghogoi to Kot the dip of the Shali limestone and overlying Shali slates is about N. 30°E., in conformity with the dip of the overlying Chails, beyond Kot the strike suddenly swings round through a right angle, and the same rocks are seen dipping to the south-east where they cross the Pandoa *khad*, to the S. by E. at Maklog, and due south by Aisha. The explanation of this remarkable difference in the behaviour of the strike of the two sets of rock is to be found in *the sudden appearance beneath the Chail series and above the Shali slates of the Upper Shali limestone*, the latter rapidly thickening to over 2,500 feet. The Chail series appears to be unaffected by this phenomenon, and it is therefore necessary for the underlying rocks to change abruptly in strike to accommodate the incoming of this great thickness of limestone. The exact manner in which the Upper Shali limestone comes in is a little complicated and can best be explained by an

Incoming of the Upper Shali limestone.

enlarged sketch-map in which the Shali slates have been subdivided by dotted lines into 3 stages.

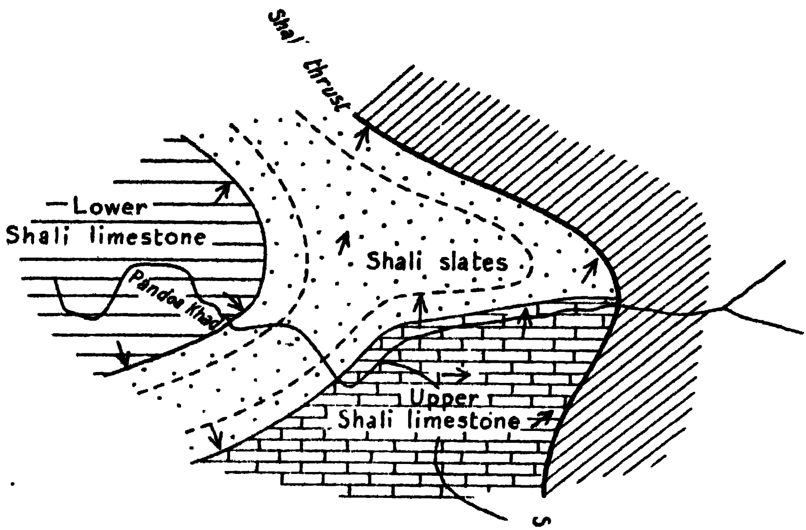


FIG. 3.—The incoming of the Upper Shali limestone.

Examination of the eastern half of the slate outcrop on the north side of the Pandoa *khud*, shows that it is a sharp fold, the axial plane of which dips northwards, for the upper stage of the slate band is seen both above and below the middle stage. To the south-west this fold dies out, and the slate band dips normally beneath the Upper Shali limestone.

The Upper Shali limestone by Tundal.

The Upper Shali limestone also appears for a short distance in the bottom of the Sutlej valley less than half a mile north-east of Tundal, where it overlies the Shali slates and extends for nearly two miles up the valley, forming the cliffs immediately above the river bed. The exact manner in which the limestone comes in here cannot easily be determined owing to the extensive gravel deposits which obscure the older geology. On the south-east side of the river it can be followed almost as far as the *khad* by Talah, beyond which it dies out.

Plate 2 is a photograph taken from Hathia, on the south-east side of the Sutlej valley, looking north, and shows very clearly the line of the Shali thrust.

Incoming of the Madhan slates.

Continuing our examination of the boundary, between the Pandoa *khad*, where the Upper Shali limestone comes in, and Nag Tikar, the prominent peak north-east of the Shali, the most important feature is the appearance of the Madhan slates between the Upper Shali limestone and the Chail series south-west of Koti. Rusty brown slates, so typical of the Madhans, are seen just over a furlong S. S. W. of Kateri, resting on massive quartzites. The latter are rather more prominently developed than is usual in the Madhans, but they are of the type that occurs in that series. These rocks rest at first directly upon the Upper Shali limestone, the Shali quartzite being absent. But a short distance further on, on the south side of the Pandoa *khad* (Garach *nala*), there is a white quartzite on top of the Shali limestone, and this is almost certainly the Shali quartzite.

Incoming of the Tertiary beds.

Continuing on towards Nag Tikar, the Madhan slates are prominently developed below Dhar, and form the precipitous cliffs overlooking the *khad* to the west of Mahewag. Further south-west, however, the Madhans temporarily die out, and the Chail series rest once more upon the Shali series. But they reappear on the east and north-east slopes of Nag Tikar, and we are here introduced for the first time to Tertiary beds. The section here, however, is complicated by the presence of some Shali limestone, which is out of place, a phenomenon that is seen to better advantage further south-west in the Nauti *khad*, and it will be discussed more fully below.

South from Nag Tikar the Tertiary beds are well developed on the dip-slopes of the Shali range, resting normally upon the Madhan slates. They are seen immediately below the Chail series for nearly four miles to the south of Nag Tikar, and in many other outcrops on the north-western slopes of the Nauti *khad*. The geology here is extremely complicated, and can only be properly shown on the 2-inch map (on the ¼-inch map, the Madhan slates and Tertiary beds have had to be grouped together). It is described in greater detail below.

Along the boundary of the Chail series the Subathus die out near Majolti, and from there to Chaba the Chail series rest either upon the Madhan slates or upon the Upper Shali limestone. There is one exception to this last statement. North-east of Guma, on the north-east slopes of the Nauti *khud* around Kathnol, there is a large outlier, or *klippe*, of the Chail series. This outlier, which is probably quite thin, rests partly upon Madhan slates, partly upon Subathu beds, and partly upon yet one more new horizon, namely Dagshai beds, the latter, where seen, resting on the Subathus. The discordant manner in which the Chail series rests upon these various horizons is well brought out on the 2-inch map, and is testimony to the discordant nature of the Chail boundary.

Klippe of Chail series by Kathnol.

Proceeding further north-west, at and around Chaba on the Sutlej the Chail series rest for the most part on the Upper Shali limestone. But by Chaba itself a thin remnant of Madhan slates is seen in the banks of the Sutlej. The Madhan slates, the Shali quartzite and the Shali limestone are here repeated by a subsidiary thrust-fault, and the slates are seen both immediately west of the Power House, on both banks of the Sutlej, and also on the south bank just east of the Power House, where they are underlain by Shali quartzite and Shali limestone in normal sequence, and overlain by Shali limestone through thrusting. The Power House itself is situated on the upper bed of quartzite, but this soon dies out to the south-east. The corresponding section on the north bank is obscured by talus, but the main boundary between the Chail series and the underlying rocks is well displayed where a small cliff formed of Chail limestone striking north-east abuts discordantly against Madhan slates striking N. N. W.

A minor thrust at Chaba.

The reservoir above is situated on the Madhan slates, which overlie the main mass of Upper Shali limestone, the quartzite having died out. Just above the reservoir on its south side there comes the second band of Shali limestone, repeated by the minor thrust. Its crushed nature can be well seen on the roadside leading from the reservoir to the Inspection Bungalow (I. B.), which is situated on it.

Since Chaba is frequently visited by travellers, and the structure is too small to be reproduced on the half-inch map, I have given

an enlarged map of the area in Fig. 4, on the scale of 4 inches to 1 mile.

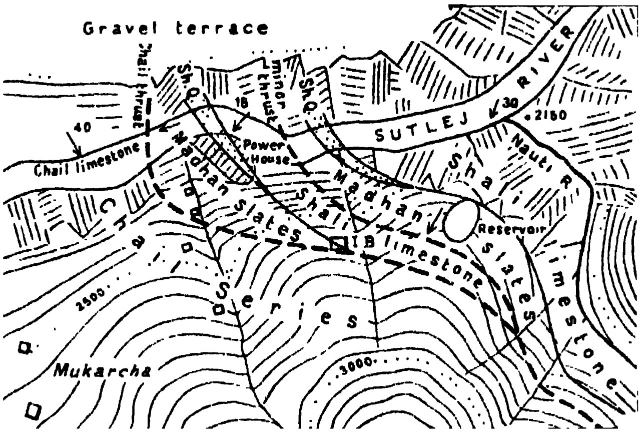


FIG. 4.—Map showing the structure around Chaba. Scale 4″ = 1 mile.

This is as far as we can trace the Chail boundary, for unfortunately the rocks north of the Sutlej, around Sakra, are entirely obscured by gravels and talus. One third of a mile north-east of Sakra, the Chails (limestone and slate, with quartzite) are again found, but the base cannot be seen. Moreover, a large fault, seen to better advantage to the north-west, further complicates the geology. The boundary of the Chail series shown on the map at this place is thus mainly conjectural.

We have now followed the course of the Chail boundary right round the Shali area. Had not the fault referred to above existed, it is possible that the course of the boundary would have been completely closed.

Before describing the complicated geology of the Nauti *khad*, we may consider the real nature of the boundary forming the base of the Chail series. As has already been stated, Medlicott was unable to understand how it was that younger rocks were found in the centre of an anticline or dome dipping in all directions beneath older rocks. Medlicott's reason for supposing the Shali series to be younger than the surrounding and apparently overlying Chail series seems to have rested upon his appreciation of their different

The nature of the Chail boundary.

grades of metamorphism. While this is perhaps not a completely sound argument as applied to the age of rocks, it does at least necessitate the introduction of a fault between the two series. As Medlicott wrote :—

> "It is not a case of simple inversion: the contiguity of the extreme types of rock involves faulting, or some equivalent supposition; and the direction of the plane of contact necessitates *reversion*, that is, a slope opposite to that which is considered normal in cases of faulting, with reference to the relative positions of the younger and older strata."

Comparison of metamorphic grade above and below the boundary.

Detailed examination of the types of rocks found in the Chail series and in the rocks below leaves no room for doubt that the former display a higher grade of metamorphism than the latter. The Chail series are typically represented by phyllites and lustrous schistose slates that proclaim their 'epi' grade of metamorphism. Accompanying these rocks there is frequently a great profusion of quartz-veins generally only one inch or less wide and a few inches or more long, but sometimes up to a foot wide and several feet long. In some cases the phyllites are so intimately penetrated by vein quartz, that the latter must make up nearly half the rock. This grade of metamorphism, although not very high, is in contrast to that displayed by the underlying rocks. In comparing the two sets of rocks it is necessary to select similar types of rock. Amongst the rocks below the Chail series, the Shali slates, the Madhan slates and the Subathu beds include pelitic types comparable to the types found in the Chail series. When these rocks are compared with the rocks of the Chail series the difference in grade of metamorphism is at once apparent. For the former are mostly ordinary clay slates that have undergone no metamorphism other than that due to the mechanical effects of compression and folding that these rocks, in common with all the rest, have undergone. The contrast is of course most marked in the case of the Subathu and Dagshai beds, which are still in the condition of shales, albeit rather jointed shales, that contain a few perfectly preserved fossils. If we compare the psammitic types of rocks, we find the same distinction. Those in the Tertiary rocks are sandstones, or rarely quartzites, that have undergone no recrystallisation, whereas rocks of similar composition in the Chail series are true metamorphic quartzites or, where sufficient sericite is present, quartz-schists.

Regarding the presence or absence of the vein quartz, the distinction is striking, especially where the Chail series overlie the Shali slates, there being an abrupt cessation of vein quartz when passing from one to the other. Even Medlicott in his rapid survey of the country remarked on this fact in his description of the section from Belu to Dhamun Nag on page 50 of his Memoir. As regards the origin of the vein quartz, it is possibly to be attributed to the thick sill of ortho-gneiss intruded into the higher parts of the Chail series. In that part of the Chail series that is some distance from the gneiss, *e.g.*, by Theog and Fagu, the vein quartz is very much less common, and this is probably significant.

One final point concerning the nature of this boundary has to be considered, and that is, if the succession is a normal uninverted or unfaulted one, then the Chail series, and with them the Simla slates, must be Tertiary in age, in fact post-Dagshai. This is inconceivable, and we are forced to the conclusion that the base of the Chail series is a fault of some kind.

We may now summarise the facts at our disposal concerning the nature of the Chail boundary. They are as follows :—

(1) A marked regional discordance is revealed by the mapping. South of the Shali the Chail series rest on Subathu and Dagshai beds. Twelve miles further north, across the Sutlej, they rest on the Middle Shali limestone. *In the interval nearly 4,000 feet of strata have disappeared.*

(2) A marked difference is to be observed in the grade of metamorphism exhibited by the rocks above and below the Chail boundary. The more metamorphosed rocks overlie the less metamorphosed.

(3) The upper rocks are generally characterised by an abundance of vein quartz, never seen in the rocks below the Chail boundary.

(4) Signs of crushing are frequently seen in the lowest rocks of the Chail series, especially where they rest on massive rocks.

(5) There is a marked distinction between the gently dipping, unfolded, sheet-like form of the Chail rocks, and the folded nature of all the underlying rocks.

(6) The structures displayed in the rocks immediately beneath the Chail boundary in the Nauti *khad*, and not seen far from this boundary, are such as to indicate intense movement along this line. These structures are described in the next section.

(7) There can be little doubt that the Chail series are pre-Tertiary in age, and yet they rest as a flat sheet upon Subathu and Dagshai beds.

Consideration of the facts summarised above forces one to the conclusion that *the base of the Chail series is a thrust-fault, and moreover an exceedingly flat one, which has forced the Chail series many miles southwards so as to lie like a mantle over the rocks of the Shali series. It is only where this mantle has been denuded away sufficiently that the underlying rocks are seen, and the Shali area is thus a true 'window' in the Alpine sense.*

This thrust, originally referred to as the Chail thrust, is now termed the Shali thrust. Although it has brought forward rocks of Chail age, it has no connection with the main Chail thrust, which occurs at a higher tectonic horizon, and it is therefore necessary to give it a separate name. It is the dominant feature in the structure of this area.

5. STRUCTURES BENEATH THE SHALI THRUST IN THE NAUTI *KHAD*.

Stated simply, the Nauti *khad* consists, on its north side, of a dip-slope of Upper Shali limestone, overlain by Shali quartzite, Madhan slates, and Tertiary beds. This is clear from the photograph given in Plate 1, where the Madhan slates and the Tertiary beds form the more subdued topography of the middle slopes of the Shali range, while towards the bottom of the valley the Shali limestone reappears, forming a steep scarp slope. On the south side these same beds dip south beneath the Chail series, and this side is mainly a scarp-slope of the Chail slates. When studied in detail, however, the structure is found to be much more complicated.

For studying the geology of this area, Dharmpur forms an excellent centre, a good place for camping being just above the main road where it crosses the second *khad* west of Balheot, about halfway between Balheot and Kandi.

(1) Recumbent folding and thrusting.

The recumbent folds to be described affect the Shali limestone, Shali quartzite and Madhan slates. Though not of very great amplitude they are very clear, and generally have their middle limbs sheared out and replaced by a thrust. The clearest example of a fold and a thrust is seen just north-west of the Balheot-Dharmpur road. The east side of the *khad* west of Balheot provides an excellent section which is worth describing in detail.

A recumbent fold by Balheot and Dharmpur.

The road running from this *khad* south-east to Balheot is situated on Shali quartzite, and this rests in proper sequence on Shali limestone. In the cliff alongside the road a very clear line is seen. Above this line there comes a crushed quartzite, which is overlain abnormally by Shali limestone. The Shali limestone forms steep cliffs, but is overlain above by more Shali quartzite, uncrushed, and this by Madhan slates, which cap this part of the spur. Examination of the rather irregular boundary between the limestone and the quartzite shows that the boundary bends right round, the quartzite turning round and under the limestone, and at the same time becoming highly crushed. It is evident that this recumbent fold is resting on a thrust-plane, the trace of which on the *khad* side is the sharp line referred to above. A photograph of this spur is given in Plate 3, with the boundaries drawn in.

It is clear that we actually have here the nose of a recumbent fold, and it is evident that this fold is resting on a normal sequence of Shali quartzite and Shali limestone, from which it is separated by a thrust. The quartzite envelope, as it turns over, becomes highly crushed and eventually dies out, and the Shali limestone further up the *khad* is seen resting upon uncrushed quartzite. Likewise the Madhan slates bend over round the nose of the fold and die out against the thrust.

If the nose of the fold be followed east of the spur towards Dharmpur, it will be found that the limestone dies out at the surface as the quartzite closes round it, while just west of Dharmpur the overlying Madhan slates also bend round and meet the underlying Madhan slates, and the fold thus completely closes. Further north, however, the nose has again been partly denuded away, and the limestone is again seen with the quartzite and Madhan slates both above and below it. All this is clearly shown on the 2-inch map.

Returning to the section in the *khad* side north-west of Balheot, we may represent the structure seen here in the following diagrammatic section:—

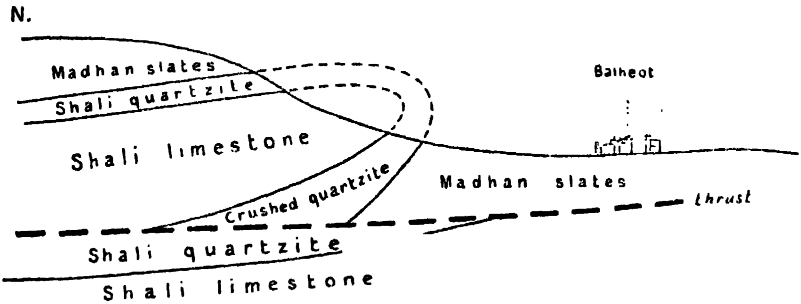


FIG. 5.—Diagrammatic section along the Balheot spur.

The way in which the quartzite envelope surrounding the limestone becomes crushed to a breccia as it approaches the thrust-plane is very convincing as to the truth of the above interpretation. We clearly have a recumbent fold with the middle limb replaced by a nearly horizontal thrust, while the same thrust has cut out the lower band of quartzite below Balheot village, so that Madhan slates rest directly on Shali limestone.

Leaving the further discussion of this area for the moment, let us go direct to Kandi, about a mile south-west of Balheot, and examine two very instructive sections. Kandi is situated on Madhan slates. On both sides of the spur these Madhan slates rest normally on the Shali quartzite and the latter on the Shali limestone, which is seen in a fine precipitous section in the deep *khad* to the west of Kandi. Proceeding north-west up the spur from Kandi the Madhan slates, owing to a south-easterly dip, soon give way to the quartzite; but where the spur becomes suddenly steep, the quartzite is overlain by a considerable thickness of Shali limestone. This boundary between the quartzite and the limestone, whether followed to the north-east round the small *khad*, or to the north-west along the road, is clearly seen to be a thrust. For not only is the quartzite overlain in reverse sequence by Shali limestone (as well as underlain by it, normally), but the base of the limestone is seen to be highly crushed for a few feet above the boundary. The thrust nature of the junction is best seen (1) on the north-east side of the *khad* north of Kandi, where the junction between the quartzite and limestone is

The Kandi spur.

very clear, with the overlying limestone brecciated for 10 or 15 feet; and (2) in a cave by the roadside along the road from Kandi to Bog, just before the first tributary shown on the 2-inch map to the north-west of ·6675, where also the limestone is brecciated. In addition to the main outcrop of Madhan slates by Kandi, there is also a small outlier of Madhan slates a short distance further up the spur, capping the quartzite; while, what is of particular interest, further north-west along the road, just south of ·6675, a small outcrop of purple and brown Madhan slate is seen for a few paces between the quartzite and overlying limestone, thus providing additional evidence for the thrust. The structure on the spur is, in fact, analogous to that by Balheot, except that the fold is not seen to close. The following diagrammatic section represents the structure here :—

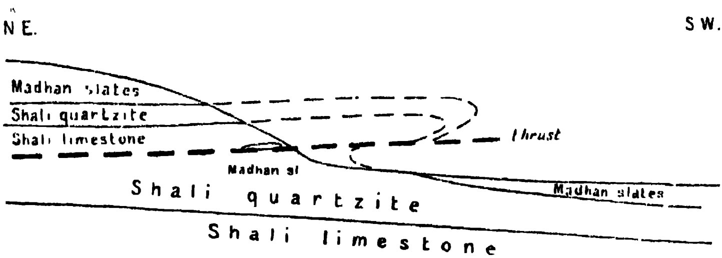


FIG. 6.—Diagrammatic section along the Kandi spur.

Interesting as this section is, an equally instructive section is to be seen on the west side of the *khad*. An excellent idea of the structure can be obtained from the road on the east side of the *khad*, *e.g.*, by the cave mentioned above. The view from this point is shown in Plate 4, and an examination of the ground in question shows that the structure is as follows :—

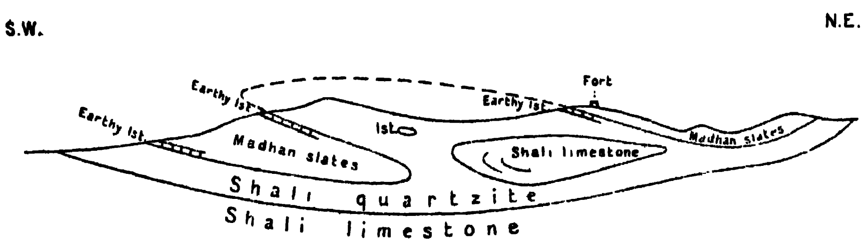


FIG. 7.—Diagrammatic section along the spur half a mile south-west of the Kandi spur.

It is clear that we have here a structure similar to that seen on the east side of the *khad*, with this difference, that there is no thrust here. Careful examination of the huge limestone lenticle shows that its upper and lower boundaries with the quartzite are normal junctions and not thrust junctions. That the quartzite—Madhan slates boundary, shown by a broken line in the air, is also the correct interpretation is clear from the geology on the far (west) side of the spur, where the quartzite fold is seen to close, and the Madhan slates are seen to be continuous around the quartzite. Further confirmation is provided by a thin bed of brown earthy limestone which occurs at the junction of the quartzite and the Madhan slates. By the old fort it comes *above* the quartzite ; but further down the spur it comes *below* the quartzite, while further down still, south-east of Bagnali, it comes *above* the quartzite once more. It is indicated in the diagram given above. It is clear in fact that we have here a recumbent fold of quartzite, with a core of limestone and an envelope of Madhan slates. These two sections on either side of the *khad* are thus of much interest, supplementing one another.

Returning once more to the *khad* west of Balheot, it is interesting to follow the lower quartzite (on which the road rests) round the *khad* to the west. It follows the road for some distance, and then rapidly becomes almost vertical and runs down the *khad* side, almost meeting a lower bed of quartzite that is continuous with the quartzite by Kandi. The limestone below the quartzite in question also bends over and down. The following section is seen on the hill side below the road :—

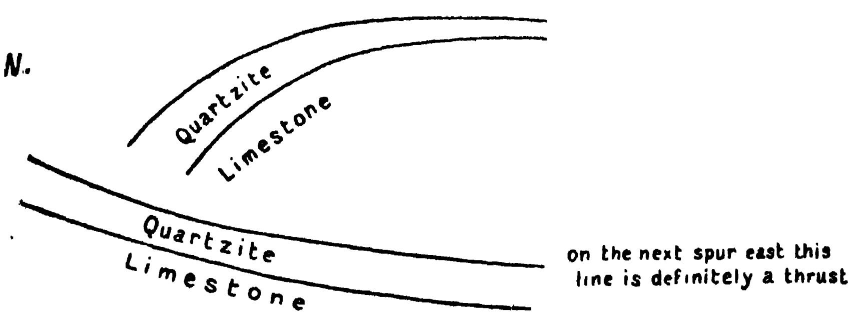


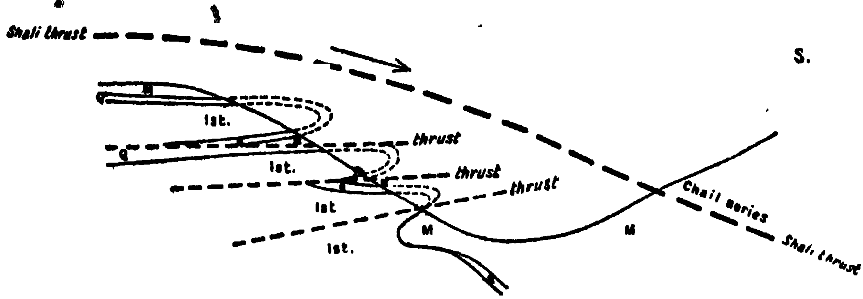
FIG. 8.—Section seen on the east side of the spur south-west of Balheot.

On account of some fields which obscure the geology over a small area, it is not possible to say whether the upper quartzite actually bends round so as to become inverted, or whether it ends abruptly against the lower quartzite. But that the top of the lower quartzite is a thrust is clear when it is followed to the east on to the Balheot spur, some three or four hundred feet below Balheot. Here is a small house, and this is situated on a thin bed of Madhans which overlies the quartzite. But a little further up the spur the quartzite is overlain by massive Shali limestone, which extends nearly up to Balheot. Just north-east of the little house, the junction of this limestone with the underlying quartzite is very clear, the top of the quartzite is highly crushed, and it is clearly a thrust. This section is very similar to the section on the Kandi spur, and a glance at the 2-inch map shows in fact that this thrust is the direct continuation of the thrust that runs from Kandi to Bog, already described above. Here, however, an extra fold and thrust have come in above it, and it is clear that the bend over of this quartzite and limestone on the west side of the *khad*, shown in the figure given above, is the brow of another small recumbent fold, the lower limb of which has been cut out. On the Balheot spur the brow has been denuded away.

We have not yet finished with this Balheot spur. Continuing down the spur from the house, the limestone is soon underlain by Madhan slates, without the intervention of any quartzite. The same relations are seen in the main *khad* to the east. On the west side of the spur, however, the quartzite comes in and continues west, with one small break, to join up with the quartzite by Kandi. Below this quartzite there is some more limestone and quartzite, but this, for the purpose of this description, may be neglected, as it is merely an additional open fold which closes towards Kandi. The limestone above the quartzite that we are considering continues to the east as far as the *khad* on the east side of the Kandi spur, and is seen just above the road. It is evident that this band of limestone is a flat fold that closes just west of the *khad* N. N. E. of Kandi. But there has probably been some thrusting as well, since the top of the quartzite below it, just east of the *khad*, is very crushed. As already indicated, east of the Balheot spur the quartzite is missing, and the Madhan slates are seen dipping beneath the limestone, in inverted sequence. A little way east of the main *khad*, just below Daro, the quartzite is seen above the limestone

and is overlain by Madhan slates. We see here, in fact, the closing of the third and lowest recumbent fold, a fold that is bounded in part by a thrust at its base, as shown by the disappearance of the quartzite in the main *khad*, and by the brecciation of the quartzite N. N. E. of Kandi. This third recumbent fold is no doubt of small amplitude, but its existence is none the less clear.

We may now give a diagrammatic section along the line of the Balheot spur, showing the three recumbent folds with their thrusts :—



M = Madhan slates Q = Shali quartzite. lst = Shali limestone.

FIG. 9.—Diagrammatic section along the Balheot spur.

That these recumbent folds with their thrusts owe their origin to the Shali thrust above, having been induced by that thrust as it forced the Chail series many miles southwards, can hardly be doubted.

(2) The structure of Baraihna hill.

Certain structures that occur in association with the Shali thrust, and provide further evidence for its existence, may now be briefly described. They are best seen in the neighbourhood of Majrahna and Baraihna, between Dharmpur and Nag Tikar.

Immediately below and north-east of Dharmpur the *khad* is spanned by a small bridge. Ascending the opposite side of the *khad*, one first passes over about 800 feet of Madhan slates. These are overlain by about 50 feet of Subathu beds, which contain a few casts of lamellibranchs. Immediately above these come the Chail series, in which the typical finely banded limestone is conspicuous.

Following the Subathu-Chail boundary northwards, an outcrop of Shali limestone, with a little Shali quartzite, is seen on the next spur at about E. 15°N. of Kamalti. It is really a long lenticle, about five or six feet thick, and it comes immediately above the

Subathu beds and below the Chail series, in other words along the line of the Shali thrust.

Continuing northwards, the Shali limestone, with a little Shali quartzite, reappears in force at a little south of east of the more northerly part of Chila village. Here it is fully 50-60 feet thick, and forms a small vertical cliff that can be recognised as Shali limestone from a distance.

Further north, below the large 'N' on the 2-inch map, the Subathu beds are overlain by a patch of Madhan slates (in addition of course to being underlain by them), but there is here no Shali limestone. However, immediately north of the next tributary, that runs down from Nagad, a prominent bed of Shali limestone is seen by and above the road. At its thickest it is about 125 feet thick, and is overlain by the Chail series.

A similar outcrop of Shali limestone is seen on the south side of Roni, while others occur much further south by Daro and Shiwa. All these outcrops are located along the line of the Shali thrust.

Leaving the Shali thrust, we may now examine the hill immediately above Baraihna. This hill has been referred to by both Palmer and Pilgrim, but neither, for lack of time, appreciated its real structure. In effect we have here a capping of Shali limestone, Shali quartzite and Madhan slates resting partly upon Subathu beds and partly upon Madhan slates. The latter also rest upon Subathu beds. It is clear that we are dealing with a section very similar to that described above, on the opposite side of the *khad*, except that the Chail series have been denuded away. A diagrammatic section through Baraihna hill and across the *khad* is given below in Fig. 10.

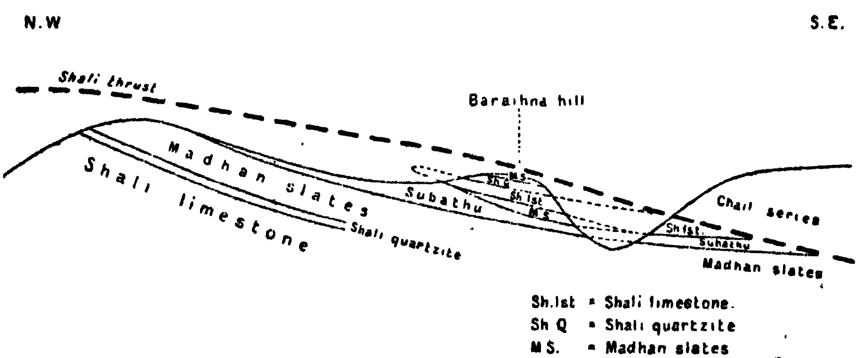


FIG. 10.—Diagrammatic section through Baraihna hill.

A somewhat similar section is seen around Majrahna, where a patch of Shali limestone rests upon the Tertiary beds. The latter, however, include here a higher horizon, namely Dagshai beds, consisting of carmine shales with purple and green sandstones.

Considering all the above sections, the conclusion seems forced upon us that these slices of Shali limestone and other rocks *have been torn off the main Shali outcrop to the north-west and dragged along by the Shali thrust so as to come to lie upon the autochthonous Tertiary rocks.* A similar explanation must also apply to the numerous outcrops of Shali limestone around Kathnol, already described and referred to again below.

Such structures, occurring as they do immediately beneath the Shali thrust, are strong additional evidence as to the reality of the thrust.

(3) The Kathnol *klippe.*

The discordance at the base of the Chail series.

The roughly circular outlier of Chail rocks that occurs around Kathnol, north-east of Guma, has already been mentioned on page 145. It is important as providing further evidence that the Chail series once extended right over the Shali area, having since been denuded away. It is also of interest in showing very clearly the marked discordance that separates the Chail series from the rocks that occur below, for they are seen resting successively on Madhan slates, Subathu beds and Dagshai beds.

Pilgrim, during a traverse across the Shali area, had noticed Subathu beds east of Kathnol, but had not seen the Dagshai beds. The two are in places either interfolded or interthrust, but owing to their rather structureless character the exact relations are uncertain.

Thrust slices of Shali limestone.

A matter of some interest is the appearance here and there of outcrops of Shali limestone, which are evidently similar in origin to those described above, by Baraihna hill. Thus, about three-quarters of a mile E. by N. of Kathnol, are two outcrops of Shali limestone resting upon the Dagshai beds. Another outcrop is seen half a mile south-east of Kathnol. This bed of limestone comes immediately beneath the Chail series and above the Dagshai beds, and is thus exactly similar in position to the outcrops south-east of

Baraihna hill. Another such outcrop is seen about three-quarters of a mile S. by W. of Kathnol.

Less easy to understand are the outcrops of Shali limestone that are found *within* the Chail series. Such are seen at Kathnol itself and at several places north-west of Kathnol. They are evidently similar in origin to the other outcrops, but have been thrust into or caught up within the Chail series as it moved over the area. A similar, but much larger, example, seen between Chaba and Seoni, in the Sutlej valley, is described below.

One further point of interest in this area must be referred to. For a short distance along the north side of the Nauti *khad*, due south of Kathnol, the Chail series are seen dipping north beneath the Shali series. The exact structure here is not easy to make out, owing to lack of good exposures at critical points. East of Dengal the Shali limestone, with a thin covering of Madhan slates, is clearly seen dipping beneath the Chail series. In the other direction, north-west of Badewan, the same is seen, though the Madhan slates are in most places missing. In between, for about a mile and a half, the Chail series, here dominantly carbonaceous slates, are seen dipping northwards. The only interpretation I can give is that the Chail series, in moving southwards along the Shali thrust has, so to speak, overrun itself; or, put in another way, part of the Chail sheet has lagged behind and been overrun by the faster moving mass behind, and so been forced to buckle down and backwards.

A plunging nappe.

The only alternative is that there has been some sharp folding here subsequent to the main thrusting. This, however, seems unlikely, since there is no sign of such folding throughout the rest of this area. If the former suggestion is correct, it would represent what the Alpine geologists term a plunging *nappe*, and this was the view that Dr. Arnold Heim took when I discussed the point with him at Simla.

Before concluding this section, one more outcrop of Shali limestone must be referred to, as its position is rather anomalous. About half way between Chaba and Seoni, where the main road, after leaving Shakrori, approaches close to the river, a mass of Shali limestone is seen both above and below the road, the portion below the road being capped by Shali quartzite. By the river itself, on the south-

Shali limestone within the Chail series.

east side of the big bend, the Shali limestone has a gentle northerly dip, while the adjacent Chail slaty limestone has a steep northeasterly dip, suggesting a fault. However, closer examination of the outcrop suggests that there is no need to suppose a fault, but that the rather incompetent rocks of the Chail series have been moulded around an irregular mass of more resistant Shali limestone and quartzite. Above the road the Shali limestone is overlain by the Chail series, while below the road, a little east of milestone 22, it is also underlain by the Chail series. We appear, therefore, to have a mass of Shali limestone within the Chail series, quite isolated from any other Shali outcrop, and thus similar to the much smaller outcrops of Shali limestone referred to above as occurring within the Chail series near Kathnol. It is curious, however, that while the Shali limestone below the road is capped by about 20 feet of Shali quartzite, above the road it is overlain directly by the Chail series; which suggests that there is a thrust within the Shali mass, approximately along the line of the road, repeating the Shali limestone but not the Shali quartzite.

6. THE RELATION OF THE SHALI WINDOW TO THE SIMLA-KROL AREA.

Having given in the preceding sections a short account of the structure of this area, it will be fitting if I conclude this paper with a short section discussing the relation of this area to the Simla-Krol area further south.

Reappearance of the Shali series at Tatapani.

Westwards from Chaba both sides of the Sutlej valley are occupied by rocks of the Chail series. But at Tatapani, some five miles west of Chaba, the Shali series reappears once more. The section downstream from Tatapani is particularly interesting, as it provides further confirmation of the truth of the conclusion already arrived at regarding the former extension of the Chail series over the Shali area.

Due to the development of a pitch.

The general structure of the Sutlej valley between Chaba and Tatapani is that of an anticlinorium. At Tatapani, however, the anticline develops a pitch to the east, and the rocks beneath the Chail series forming the core of the anticline are brought up to the west. We see here, in fact, the Shali series (Lower Shali limestone) pitch-

ing up from beneath the overlying Chail series, thus providing further evidence that the Shali series really underlies the Chail series throughout this area. In the Shali area proper the same structure is seen at a much higher level, and the Chail covering has been denuded away. But at Tatapani the Chail covering is still present, and the underlying Shali series is only seen through the influence of the pitch. It is no doubt significant that the line of junction between the two series, which is of course the Shali thrust, exactly coincides with the well-known hot springs after which the place takes its name—Tatapani.

The Shali thrust traced to beyond Arki.

From Tatapani the line of the Shali thrust on the south side of the Sutlej valley runs nearly due west for about eight miles, and then rapidly swings round through a right angle to run south towards Arki. In the same manner the strike of the rocks above and below the thrust also swings round. It is of interest to note that from Tatapani westwards a new horizon appears immediately beneath the Shali thrust, namely vesicular greenstones. These are clearly of volcanic origin, and there are reasons for believing them to represent the Panjal trap. They are seen overlying the Shali limestone to as far as about five miles north of Arki, where the Chail series overlaps them along the line of the Shali thrust and comes to rest once more upon the Shali limestone.

The Shali limestone is here quite thin and is overlain on its west side by the main spread of Tertiary rocks. About a mile west-north-west of Arki the last of the Shali limestone is seen, and southwards from here the Chail series directly overlies the Tertiary beds, and forms a well-marked scarp facing west.

The Shali thrust probably continuous with the Giri thrust.

The Shali thrust has thus been followed to within about a mile and a half of Hat Kot. Its further course is not known for certain; but from what is known of the strike of the rocks in this area, the thrust must run south-south-east and south-east from Hat Kot, and this direction will bring it directly to Kandaghat, *and therefore into continuity with the Giri thrust.*

The Shali series probably homotaxial with the Krol series.

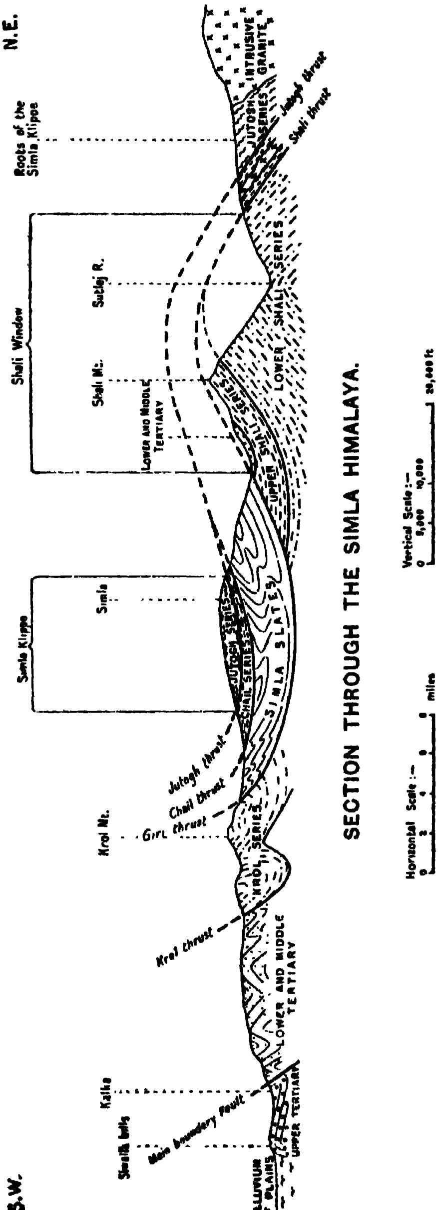
This conclusion, if correct, is of great interest, for it means that one and the same thrust has brought older rocks to overlie the Shali series to the north of Simla, and the Krol series to the south of Simla, which is suggestive of these two great limestone series

being of the same age. It is true that there is a gap of about 15 miles between the last exposure of the Shali limestone west of Arki and the Krol limestone of the Krol mountain. But it is unlikely that two such thick series of limestone, occurring in the same tectonic position, are different in age, though it must be admitted that their lithological sequence is not identical. There, however, the problem must be left for the time being.

Finally, brief reference may be made to a tentative conclusion which has gradually emerged as mapping has proceeded, namely that the Chail series are the metamorphosed equivalent of the Simla slates.

The Chail series metamorphosed Simla slates.

Pilgrim, after examining the Naldera area north of Simla, concluded that the rocks below the Naldera limestone were the lowest stage of the Chail series, a conclusion with which the writer is in agreement except that the Naldera limestone is regarded as part of this series. Overlying these rocks comes the main outcrop of the Simla slates, extending up to Simla. Very careful examination of the zone of rocks that forms the base of the Simla slates and the top of the Lower Chails, right across sheet 53-E/4, has failed, however, to reveal any break in the sequence such as might have been expected had the Simla slates been laid down upon a surface of Lower Chails with the Middle and Upper Chails missing. Moreover, these Lower Chails are, in this area, no more metamorphosed than the overlying Simla slates. It is only when traced towards the north-east that the Lower Chails gradually assume a higher grade of metamorphism, a change in which the Simla slates are precluded from sharing owing to their main outcrop not extending far in that direction. The lithology of the Middle and Upper Chails is also very similar to that of the Simla slates, and it is therefore tentatively concluded that the two are one and the same series, the Simla slates at and north of Simla representing the Middle and Upper Chails. The difference which these two series have hitherto been held to display is most marked where the Chail series have been brought by thrusting from the north-east (where they were more highly metamorphosed) to rest directly upon the Simla slates, as in the Chor area. In that area the difference between the two is very marked; and since it was there that the two series were first mapped, the difference due to metamorphism obscured the possibility that they might belong to the same series.



SECTION THROUGH THE SIMLA HIMALAYA.

FIG. 11.

In the section given in Fig. 11, the Simla slates as shown include the Lower Chails of the Naldera area. Where, however, they reappear on the north side of the Sutlej valley, more highly metamorphosed, they are represented in the section by the same character as the Chails of the Simla area. It was thought best to represent the rocks thus, until the identity of the two series had been established beyond doubt.

In Fig. 11 an attempt has been made to show the structure of the whole Shali-Simla-Krol area. The outstanding tectonic features are (1) the Shali window, and (2) the Simla *klippe*. The roots of the latter (Jutogh series) have now been found north of the Sutlej valley, while it is likely that in the Shali window we see the roots of the Krol Nappe, for Mr. J. B. Auden has shown that the Krol belt is not autochthonous but a *nappe*.

Conclusion.

The whole problem of the geology of the Simla hills was really succinctly stated by Medlicott when he wrote on page 51 of his memoir :—

"The stratigraphical phenomena which I have attempted to describe in the last few paragraphs (in the Shali area) form a companion puzzle to what we have seen on the Chor. There we have a three-sided convergence of dip upon what seemed to be a point of special elevation; here we have a three-sided divergence of dip in what seems to be a band of special depression".

The problem thus stated is solved when it is understood that we are dealing with an immense thrust that has brought a sheet of older rocks to rest more or less horizontally upon younger rocks, the whole having been subsequently gently warped and partly denuded. In modern terminology, the former area referred to by Medlicott (the Chor-Simla area) is a *klippe* of older rocks resting upon younger. The latter area (the Shali area) is a *window* of younger rocks appearing from beneath older.

7. EXPLANATION OF PLATES.

PLATE 1.—The Shali Range, viewed from the south.

PLATE 2.—View north-east from Hathia, showing the line of the Shali thrust.

PLATE 3.—The west side of Balheot spur, showing a recumbent fold riding on a thrust plane.

PLATE 4.—The south-west side of the *khad* west of Kandi, showing a fold without a thrust.

PLATE 5.—Geological map of the Shali window. Scale, 1 inch=2 miles.

PLATE 6.—Geological map of the Shali range and the Nauti *khad*. Scale, 2 inches =1 mile.

PROVISIONAL STATISTICS OF SOME OF THE MORE IMPORTANT INDIAN MINERALS FOR 1938. BY A. M. HERON, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.R.A.S.B., *Director, Geological Survey of India.*

"The Mineral Production of India" is compiled annually in August for the previous year and is published, usually in October, in Part 3 of the *Records* of the Geological Survey of India.

Owing to the very varied sources from which these statistics are derived and the delays, not attributable to the Geological Survey of India, in obtaining them, it has been found impossible to produce this detailed review earlier in the year. It has, however, been felt that a less complete and less accurate but substantially earlier issue of statistics relating to a few of the more important minerals produced in India would be of interest to the public.

These figures must be considered as provisional and partial only; the revised and complete statistics will be issued as usual in Part 3 of this volume. The figures in brackets give the final productions for 1937.

Antimonial lead . . . The production by the Burma Corporation, Ltd., amounted to 1,200 tons in 1938 (1,150 tons). This product contains 81·76 per cent. of lead, 17·59 per cent. of antimony, 0·22 per cent. of copper and 2·93 ozs. of silver to the ton.

Chromite . . . . The production in Bihar amounted to 4,819 tons (7,678 tons), in Baluchistan 22,409 tons (27,164 tons), in Seraikela State 94 tons (520 tons) and in Mysore State 11,135 tons (26,400 tons).

Coal . . . . . 25,209,263 tons were raised from the coal mines worked under the Indian Mines Act (22,313,205 tons).

Cobalt .	See Nickel speiss.
Copper .	The production of copper-ore by the Indian Copper Corporation Ltd., amounted to 288,076 tons (371,458 tons). A total of 296,924 short tons (374,742 short tons) of ore was treated in the mill and the production of refined copper amounted to 5,330 long tons (6,830 long tons).
Copper-matte	5,900 tons (7,750 tons) were produced by the Burma Corporation, Ltd. This product contains 42·46 per cent. of copper, 28·76 per cent. of lead and 71·61 ozs. of silver to the ton.
Gold	321,334 ozs. of gold were produced from the Kolar goldfields in Mysore State (330,710 ozs.). The production from the operations of the Burma Corporation, Ltd., at Bawdwin, Burma, amounted to 1,063 ozs. (894 ozs.).
Ilmenite .	The production in Travancore State amounted to 252,220 tons (181,047 tons).
Iron .	2,839,779 tons of iron-ore were produced by the principal mining companies in Bihar and the Eastern States Agency (2,837,998 tons). The production by the Burma Corporation, Ltd., from their mines at Wetwun, near Maymyo, Burma, amounted to 18,050 tons (25,426 tons). This is used as a flux in smelting lead.
Lead	The production of lead-ore at the Burma Corporation Bawdwin mines in Burma amounted to 472,100 tons (476,896 tons), the total amount of metal extracted was 78,900 tons (77,650 tons) including 1,200 tons (1,150 tons) of antimonial lead.

Magnesite . .	The production of crude magnesite by the Salem Magnesite Syndicate Ltd., Salem, Madras, amounted to 22,930 tons (23,782 tons). The production in Mysore State amounted to 2,609 tons (2,384 tons).
Manganese-ore	887,406 tons were produced during the year (1,051,594 tons).
Mica . .	268,348 cwts. of mica, including splittings, were exported from India during the year (297,343 cwts.).
Monazite .	The production in Travancore State amounted to 5,220 tons (3,081 tons).
Nickel speiss .	The production by the Burma Corporation, Ltd., amounted to 3,015 tons (4,020 tons). This product contains 31·32 per cent. of nickel, 8·60 per cent. of copper, 6·69 per cent. of cobalt and 15·13 ozs. of silver to the ton.
Petroleum .	The production in Assam amounted to 65,968,951 gallons (65,718,437 gallons), in the Punjab 21,419,200 gallons (9,939,420 gallons) and Burma 264,311,190 gallons (274,664,365 gallons).
Salt . . .	The production of salt amounted to 1,422,647 tons (1,493,021 tons). The production in Aden amounted to 278,047 tons (355,166 tons) and in Burma 38,698 tons (53,813 tons).
Saltpetre . .	172,524 cwts. were exported from India during the year (167,147 cwts.).
Silver . . .	The production from the Burma Corporation, Ltd., Bawdwin Mines, amounted to 5,920,000 ozs. (6,180,000 ozs.) and that from the Kolar gold mines in Mysore State 26,794 ozs. (24,642 ozs.).

Tin concentrates	5,085 tons were produced in Burma including Karenni State (6,622 tons).
Tungsten concentrates	2,877 tons were produced in Burma including Karenni State (4,998 tons).
Zinc concentrates .	60,744 tons were produced by the Burma Corporation Ltd., from their mines at Bawdwin, Burma (73,552 tons).
Zircon	The production in Travancore State amounted to 1,350 tons (1,329 tons).

MISCELLANEOUS NOTE.

Quarterly Statistics of production of Coal, Gold and Petroleum, in India and Burma, October to December, 1938.

Coal.

—	October.	November.	December.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	18,624	21,286	22,575	62,485
Baluchistan	1,091	721	536	2,348
Bengal	553,385	623,418	723,074	1,899,877
Bihar	1,129,685	1,137,636	1,300,606	3,567,927
Orissa	3,545	4,054	4,850	12,449
Central Provinces . . .	115,978	140,101	159,385	415,464
Punjab	15,936	17,482	18,696	52,114
TOTAL .	1,838,244	1,944,698	2,229,722	6,012,664

Gold.

—	October.	November.	December.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,628	8,382	9,244	26,254
The Champion Reef Gold Mines of India, Ltd.	5,997	5,781	5,977	17,755
The Ooregum Gold Mining Company of India, Ltd.	4,313	4,299	4,821	13,433
The Nundydroog Mines, Ltd.	8,376	8,097	8,382	24,855
TOTAL .	27,314	26,559	28,424	82,297

Petroleum.

—	Crude Petroleum.	Total gasolene from natural gas.*
	Gallons.	Gallons.
Assam	16,441,005	*Nil.*
Punjab	5,312,760	123,369
TOTAL .	21,753,765	123,369
Burma	64,659,303	2,863,305

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

A. M. HERON.

MGIPC—M—VIII-1-28—22-5-39—800.

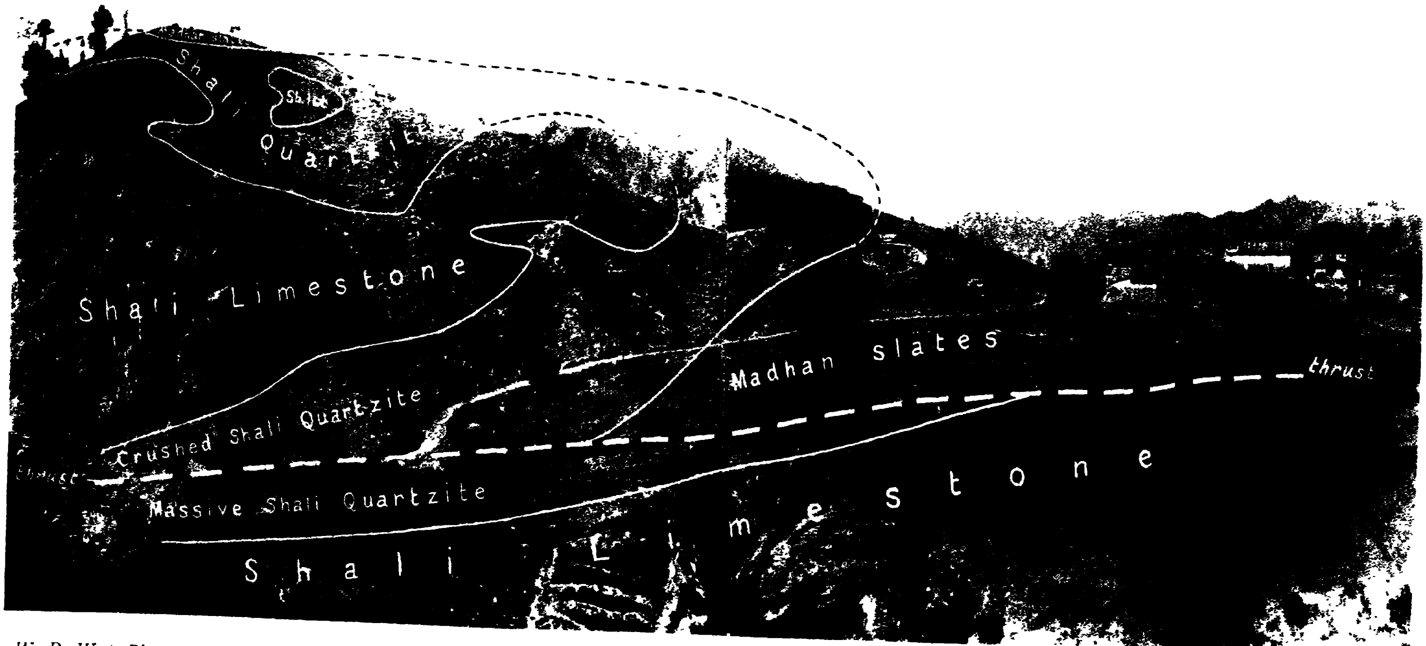
W. D. West, Photo. *G. S. I., Calcutta.*

THE SHALI RANGE, VIEWED FROM THE SOUTH.

W. D. West, Photo.

G. S. I., Calcutta

VIEW NORTH-EAST FROM HATHIA, SHOWING THE LINE OF THE SHALI THRUST.

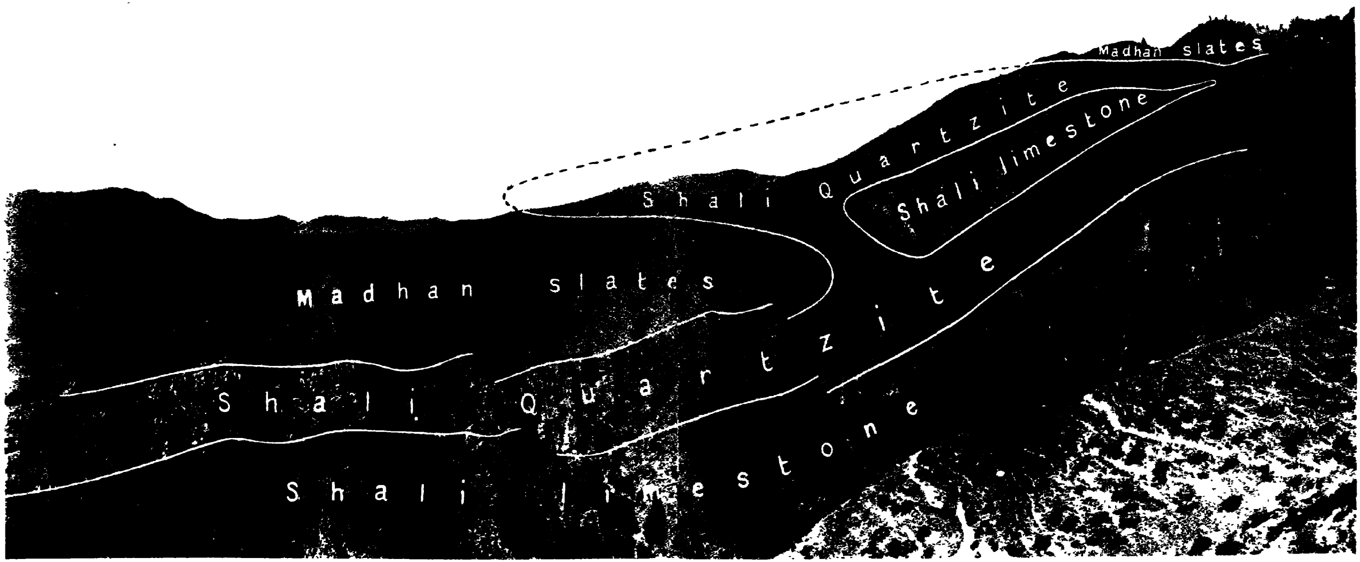


W. D. West, Photo.

G. S. I., Calcutta.

THE WEST SIDE OF BALHEOT SPUR. SHOWING A RECUMBENT FOLD RIDING ON A THRUST PLANE.

Records, Vol. 74, Pl. 4.



W. D. West. Photo.

G. S. I., Calcutta.

THE SOUTH-WEST SIDE OF THE *KHAD* WEST OF KANDI, SHOWING A FOLD WITHOUT A THRUST.

④ RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA

Part 2] 1939 [September

The Lachi Series of North Sikkim and the Age of the Rocks forming Mount Everest. By L. R. Wager, M.A., B.Sc., F.G.S. (With Plates 7 to 11.)

CONTENTS.

I. INTRODUCTION.

During the first Mount Everest Expedition in 1921 scientific investigations in the country traversed were part of the programme and Dr. A. M. Heron of the Geological Survey of India mapped an extensive area north of Mount Everest and west of Tengkye Dzong [1922 (1) and (2)]. Subsequent expeditions have concentrated on the one objective of climbing the mountain, yet incidental scientific work has often been accomplished. In 1924 Mr. N. E. Odell was able to make valuable geological and geomorphological observations especially in the neighbourhood of Mount Everest and the upper Rongshar Valley (1924, 1925), and in 1933, in intervals between the main business of the expedition, I was able to make various geological observations along the northern edge of the Himalaya from the Chumbi Valley to Mount Everest (1934, 1937). In reviewing our

present knowledge of the geology of north Sikkim and the Everest region, some of the new results obtained in 1933, were outlined; among these was the finding of specifically identifiable fossils in the Lachi hills in north Sikkim. From a cursory examination, Dr. H. M. Muir-Wood, of the British Museum (Natural History) considered that these fossils were Lower Permian in age. She has now examined in detail all the specimens at present available and has decided that they are Upper Permian, a horizon not before proved with certainty north of the Eastern Himalaya. In the present paper the field occurrence of these fossils is described and their bearing on the stratigraphy of the region is discussed. It should be considered as complementary to Dr. Muir-Wood's and Dr. K. P. Oakley's palæontological work which is to be published in *Palæontologia Indica.*

When I heard that my friend Mr. J. B. Auden of the Geological Survey of India was to visit north Sikkim in 1934 I hoped that he would be able to collect more fossils from the localities on Lachi and make fuller stratigraphical observations. Owing to early winter snow and shortage of time, he was unable to re-visit the localities where I had found the Upper Permian fossils, nor did he find the same horizon elsewhere, but instead, only a short distance away, he discovered a well-preserved Triassic fauna which is to be described by Dr. M. R. Sahni.[1] Auden (1935) has described the rocks in which the fossils occur and has made certain stratigraphical deductions from his own and my observations which are considered below.

II. GEOLOGY OF THE LACHI HILLS.

Lachi is the name given to a rounded hill just over 18,000 ft. high which forms a culmination on a northward extending spur from the Kangchima-Pauhunri range of north Sikkim. To the north of the hill the Lechha Chanbo Chu, the main headwater of the Tista, flows in a broad valley at a height of 16,000 to 16,500 ft. The name Lachi appears on the quarter inch, Survey of India map (sheet 77-D and 78-A); it is not found on Hooker's original map though the spur is clearly marked and also figures prominently in two of his plates (1854, pls. VIII and IX). In 1933 a diagrammatic map of the Lachi spur was made on the basis of the official quarter-inch map. On this the main fossil localities are given in relation to the summits and saddles (fig. 1), and they are also shown on the panorama of the range (Plate 1), taken from near the south end of Tso Lhamo.

[1] This fauna is of Upper Muschelkalk age. *M. R. Sahni.*

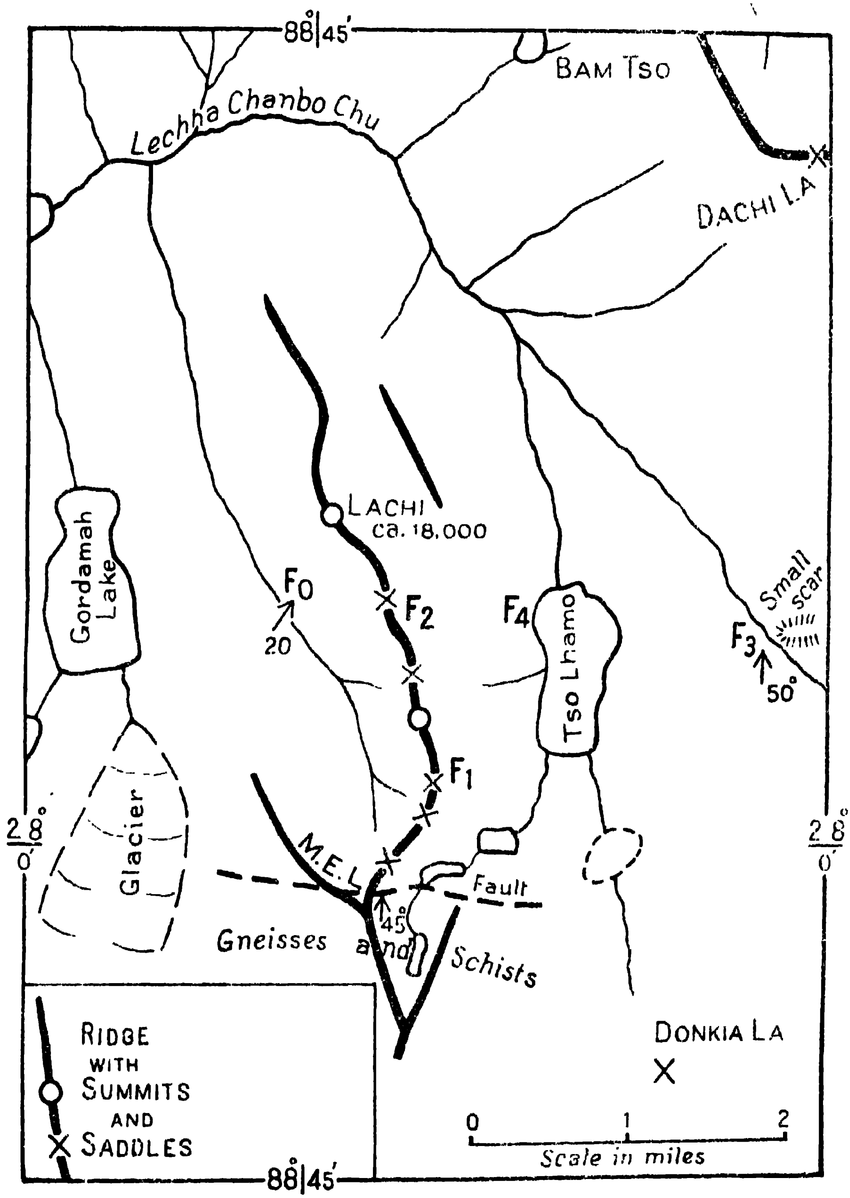


Fig. 1.—Diagrammatic map of the area around Lachi.

The relatively soft sedimentary rocks forming the spur have disintegrated easily ; outcrops are scarce and solifluxion has carried trails of material far from their sources and added to the difficulty of geological mapping. There is clear evidence from moraines that not long ago a powerful glacier occupied the valley of the Lechha Chanbo Chu to the north of Lachi. but this did not overtop the low watershed between Sikkim and Tibet, which only rises 1,000 to 1,500 ft. above the valley. Nor did the glacier ascend the Lachi hills for more than about 500 ft., as the top 1,500 ft. is free from erratics. The low ridge between Gordamah lake and the valley immediately west of Lachi has no exposure of solid rock ; it is apparently a huge lateral moraine which pushes out some way towards the main valley, and then ends abruptly. It represents moraine put down when the district was under maximum glaciation, and it ends abruptly where the side glacier joined the powerful glacier in the main valley. It is worth recording that Gordamah lake is not dammed by a terminal moraine of a glacier occupying the side valley, but by a small lateral moraine put down by the main glacier of the Lechha Chanbo valley during a waning stage.

At the southern end of the Lachi spur there is a corrie containing a small lake which drains by means of two other small lakes into Tso Lhamo. The rocks of the corrie consist of biotite-gneiss, often with large porphyroblastic felspars, and occasional reefs of highly metamorphosed sediments ; the dips are northerly. Sheared aplites are common and a few unaffected by pressure may be found ; both contain tourmaline. Zones of crushing, dipping north at 20-45°, are frequent and flinty crush rock is developed along them. Passing north along the ridge bounding the corrie on the west, the amount of crushing increases and the solid rock is largely hidden by its own scree. Then small exposures of much shattered limestone appear, and, although there is extensive scree-cover, the limestone which is probably about 300 ft. thick, can be proved to form a terrace stretching for several hundred yards east and west. In the sides of the corrie the junction between the gneisses and the limestone is to be seen dipping approximately north at 45° (Plate 1). The limestone is a massive deposit, free from argillaceous material but containing abundant small, evenly graded, sand-grains of quartz, felspar and mica, and it is lithologically so similar to the Mount Everest limestone (defined in Wager, 1934, p. 322) that it may unhesitatingly be put down as such. In this locality, as also at

28,000 feet on Mount Everest, the rock has been much shattered and re-cemented but not much marmorised, and no veins of granite nor aplite were found cutting it.

At the entrance to the Rongbuk (see plate 5) valley the lower part of the Mount Everest limestone series is injected by granite sills yet, a hundred feet above, the only obvious metamorphic effect is a slight hardening, and veining by granite does not occur. It is remarkable how effectively about a hundred feet of limestone has blanketed the rest from granite injection and metamorphism. The biotite-gneisses found below the limestone on the Lachi spur are much more abundant relative to the sediment than at the mouth of the Rongbuk valley, and, despite the evidence just given, I believe a fault or unconformity must separate the limestone from the gneisses. No signs of a basement bed to the limestone series are to be seen, nor weathering of the upper part of the gneiss. On the other hand, there are abundant signs of violent movement, so that I regard the junction, which dips north at about 45°, as a fault plane.[1] The Mount Everest limestone is at least a thousand feet thick in Lhonak, to the west, and probably the same at Dothak in the Chumbi valley, to the east, and it is likely therefore that on Lachi the fault cuts out much of the limestone. It is noteworthy that the postulated fault is apparently a normal one and not a thrust although it has a relatively low dip.

Exposures are frequent along the ridge towards Lachi and it is clear that above the limestone there is a thick succession of quartzites, hardened shales and silts. Where the ridge changes from a north-easterly to a northerly direction, there are two small saddles close together, and at the more northerly (Locality F_1) a thin limestone about 10 feet thick occurs, from which several immature corals and a small gastropod were obtained. Above is a shale 50 feet thick and then a pebbly series several hundred feet thick which forms the next mile of ridge. The lower part of the Pebble beds is a hardened silt with sporadic pebbles, next is a pebbly, light-coloured shale, and at the top is a pebbly sandstone which in places becomes a fine-grained conglomerate. The Pebble series was also found at the south-west foot of Lachi, where the dip was roughly determined as 20° to the north-east. It is here that I collected the specimens which Auden has briefly described (1935, pp. 151-2 and pp. 155-6).

[1] In this respect Auden has not correctly stated my views. *Op. cit.*, p. 154.

The largest pebbles noticed were 4 inches in diameter and the most abundant were the dark quartzites. The small fragments of brownish pink limestone were by no means rare, but only one specimen of a granite pebble was obtained. The pebbles are remarkable in that they occur sporadically in the silty matrix. Auden considers that these pebble beds resemble the Blaini tillite of the Simla-Mussoorie foothills and suggests that they are either of glacial or pyroclastic origin (1935, pp. 155-6.) I have seen no evidence to suggest pyroclastic origin but it is certainly remarkable how large pebbles occur scattered at wide intervals in a fine-grained matrix, thus giving an unusual lithology, and it is valuable to have Auden's comparison with the Blaini and other boulder beds with which he is familiar.

The highly fossiliferous, calcareous sandstone from which most of the fossils examined by Dr. Muir-Wood come, overlies the Pebble beds and is well exposed at the first saddle to the south-east of the highest point of Lachi (Locality F_2). This horizon, of which the thickness was roughly judged as 300 feet, can be traced by means of loose blocks across the south-west slopes of Lachi. The bulk of the fossils were obtained at the saddle on the ridge, but a few came from the scree slopes on the south-west face of the hill (Locality F_0).

Above the fossiliferous sandstone there is a thick quartzite which forms the summit of Lachi and in descending the northern ridge of Lachi there follows a succession of quartzites and shales dipping steeply in a north-easterly direction. In these beds, during a hurried descent, no fossils were found.

The position of the dark limestones and shales containing ammonites, lamellibranchs and brachiopods of Triassic affinities, which were found by Auden in 1934, is indicated roughly on the sketch map (Locality F_4). The beds were dipping at 20° to the east-south-east and, as Auden says, they apparently overlie in stratigraphical sequence the beds from which the Upper Permian fossils come.

To the east of Tso Lhamo, so far as I could see, only one small scar of solid rock rises above the alluvium and this locality, on the river draining from Pauhunri, is apparently the one visited by Hooker in 1849 (1854, Vol. II, pp. 176-7). From the dark limestone dipping north-north-east at about 50° I obtained, besides the encrinite stems found by Hooker, certain other badly preserved fossils, among which is a calcareous alga, which will be described

by Dr. K. P. Oakley in an appendix to Dr. Muir-Wood's paper. This dark argillaceous limestone is similar to that described by Auden from the west side of Tso Lhamo, and is quite dissimilar from the arenaceous Mount Everest limestone.

The rocks of the Lachi hills are clearly much disturbed and in the field I was unwilling to place much reliance on the observed dips because it seemed likely that hill-creep was affecting the lie of the strata. The dip of 20° to the north-north-east which is shown on the map to the south-west of Lachi, seemed one of the more satisfactory values and the impression was gained that this is the general direction of dip on the whole Lachi spur, though considerably higher dips also occur. Auden's observation, however, shows that there is much variation in dip and though some may be due to hill-creep, perhaps much is due to complicated pitching folds. Hooker has a general comment on the dips in north Sikkim, which seems very true. He writes (1854, Vol. II, p. 177): "Though I believe the general strike of the rocks on this frontier to be north-west and the dip northeast, I am unable to affirm it positively: for though I took every opportunity of studying the subject, and devoted many hours to the careful measuring and recording of dips and strikes ...... I am unable to reduce these to any intelligible system." Without more knowledge of dips it is impossible to do more than guess at the thicknesses of the beds in the Lachi spur; my estimate is that between the upper Mount Everest limestone and the top of the thick quartzite forming the summit of Lachi, there are probably some 2,000 feet of sediment.

The silts and shales have been hardened by slight metamorphism but no granite veins or aplites were found, and quartz veins are rare. The age of the biotite-gneiss and associated rocks now lying below the Lachi series and the Mount Everest limestone cannot at present be decided. The problem involves both the age of the sedimentary and igneous material. Both may be earlier than the Mount Everest limestone, but if there is a low angle fault separating them from the Mount Everest limestone, as seems likely, then one or both units of the biotite-gneiss may be later in age than the limestone.

III. THE LACHI SERIES.

The sediments overlying the Mount Everest limestone on the Lachi spur probably form a series of wide distribution. They seem

to be equivalent to the upper part of Hayden's Dothak group in the Chumbi valley (1907, p. 21). Odell (1925, p. 296) found quartzites, conglomerates and shales above what would now be called the Mount Everest limestone on the Lamna La, north of Mount Everest and these are probably also the Lachi series. Being shallow-water sediments, the series is no doubt variable in development, but search will probably reveal the horizon at many other points resting on the Mount Everest limestone.

It has been suggested elsewhere (Wager 1934, pp. 325 and 333), that the sediments overlying the Mount Everest limestone on Lachi, some of which are Upper Permain from their brachiopod fauna, should be called the Lachi series. Since Auden's discovery of Triassic fossils in the rocks of the east flank of Lachi it is necessary to delimit the series more precisely. The term Lachi series should be used, I suggest, for the rocks above the Everest limestone up to, and including, the calcareous sandstone with the Upper Permian fossils. The base of the series as so defined is the horizon at which the type of sedimentation giving rise to the very characteristic Everest limestone changes to that giving shallow-water quartzites, silts, shales and pebble beds. Somewhere above the Lachi series lies the Tso Lhamo series, the name given by Auden to the rocks containing the Triassic fossils. Whether the quartzites and shales lying above the Upper Permian calcareous sandstone are to be grouped with the Lachi series or with the Tso Lhamo series must be left for future work to decide.

On Lachi, the probable sequence from above downwards with very rough estimates of thickness which may well have to be halved or doubled when the region is mapped in detail, is: -

Tso Lhamo series .	Dark limestones and shales. Probably Triassic.[1] (Exact relationships to beds below not yet proved.)
	Quartzites and shales, the lowest quartzite (*ca.* 400 feet) forming summit of Lachi.
Lachi series .	Calcareous sandstones. Upper Permian (*ca.* 300 feet).
	Pebble beds. (*ca.* 600 feet).
	Fossiliferous limestone and shales (*ca.* 50 feet).
	Quartzites, hardened silts and shales (*ca.* 600 feet).
Mount Everest limestone series.	Massive arenaceous limestone (*ca.* 200 feet). (Base cut out by fault).

IV. THE MOUNT EVEREST LIMESTONE SERIES.

In 1921 Heron proved at intervals a horizon of limestones, in places 3,000 feet thick, which stretches along the northern border

[1] See footnote page 172.

of the Himalaya to the north of Mount Everest. On the evidence of squashed productids and spirifers he considered this limestone to be approximately Permo-Triassic in age. (1922, pp. 232-3.) Three years later Odell (1925, pp. 291-3 and 295-8) showed that the summits of Mount Everest and of several surrounding peaks consist of calcareous sediments overlying a gneissic biotite series and lower calcareous series. He tentatively correlated the upper calcareous series with Heron's Permo-Triassic limestone to the north. The limestone which Heron mapped to the east and west of the Rongbuk valley is also to be found at the entrance to the valley, well exposed in a short gorge immediately below the junction of the Rong-chu and Gyachung-chu. Here there are 700 feet of massive, arenaceous limestone, and above could be seen shaly limestone not actually reached. Towards the base for a hundred feet or so the limestone becomes more pelitic, and is also much metamorphosed by thick sills of granite and granite–gneiss. The pelitic limestone passes downwards into pelites intimately injected by granitic material, these being the banded gneiss described and figured by Odell. On the whole the dip of these rocks is northerly, but there are complications and a shallow syncline was proved · dips of 20° north-north-east being obtained at one point, and a quarter of a mile further north, dips of about 20° south-south-west. Quartzites and shales occur above the limestones, and these are no doubt the same as the Lachi series. The main part of the limestone is characteristically arenaceous, but upwards it gradually becomes argillaceous and downwards it quickly passes through an argillaceous limestone stage and then gives place to the injected pelites. The limestones have been much brecciated and recemented. It is remarkable that they show so little thermal metamorphism, considering that there are thick sills of granite and granite gneiss in the lower layers.

In 1933 there was a good opportunity of examining the rocks of Mount Everest up to 28,000 feet and I found that Odell's Upper Calcareous series is undoubtedly the same as Heron's 'Permo-Trias' limestone. The so-called first and second steps, at about 28,000 feet on the north-east ridge of Mount Everest, consist of shattered and re-cemented arenaceous limestone exactly like the dominant unit at the entrance to the Rongbuk valley. Below are schistose limestones forming the so-called 'yellow slabs', and these pass downwards into dominantly pelitic sediments. The schistose

limestones of the yellow slabs and the underlying pelites correspond to the pelitic limestone and underlying, '*lit-parl-it*' injected, pelitic material which occurs in the gorge at the entrance to the Rongbuk valley.

Odell has commented with surprise on the gentle dips which are found in this highest mountain region of the world, and it is indeed remarkable to see the limestone composing the summit of Mount Everest dipping gently north to form the summits of lower peaks and then joining up with the 'Permo-Trias' limestone horizon of Heron. The lie of the rocks is shown somewhat diagrammatically in figure 2. Small faults occur, such as that running along the Hermit's Gorge near Base Camp, and also minor folding such as that noted at the entrance to the Rongbuk valley, but these have been neglected in the section.

Heron gave no name to the thick limestone which he discovered and tentatively ascribed to the 'Permo-Trias'. Odell called the same limestone on Mount Everest the Upper Calcareous series. This limestone horizon, which I was able to trace with but few breaks from Mount Everest to north Sikkim (pl. 5), will one day provide the key to the stratigraphical sequence in this part of the Himalaya, and I have suggested that it and some of the associated rocks should be called the Mount Everest limestone series. (1934, pp. 321-2 and 332-3.) Within the term should be included the somewhat pelitic limestones forming the yellow slabs on Mount Everest and found elsewhere, and also the more pelitic upper limestones which underlie the quartzites and shales of the Lachi series. Where fully developed the Mount Everest limestone series as so defined must be one or two thousand feet thick. The Mount Everest limestone is a valuable stratigraphical datum line because it is easy to recognise lithologically and has usually a marked topographic effect. It seems also to be resistant to small scale folding and to granite injection which in several cases was found to have its upward limit at the base of the Mount Everest limestone series.

During the return from the 1933 Mount Everest Expedition I saw the Mount Everest limestone series near the Doya La, where Heron also studied it. Here it is overlain by quartzites and shales which I believe represent the Lachi series.[1] It is conspicuous again in the valley of the Phung Chu to the west of Sankar Ri,

[1] Dr. Muir-Wood has re-examined Heron's collection of fossils and has obtained further evidence for this view.

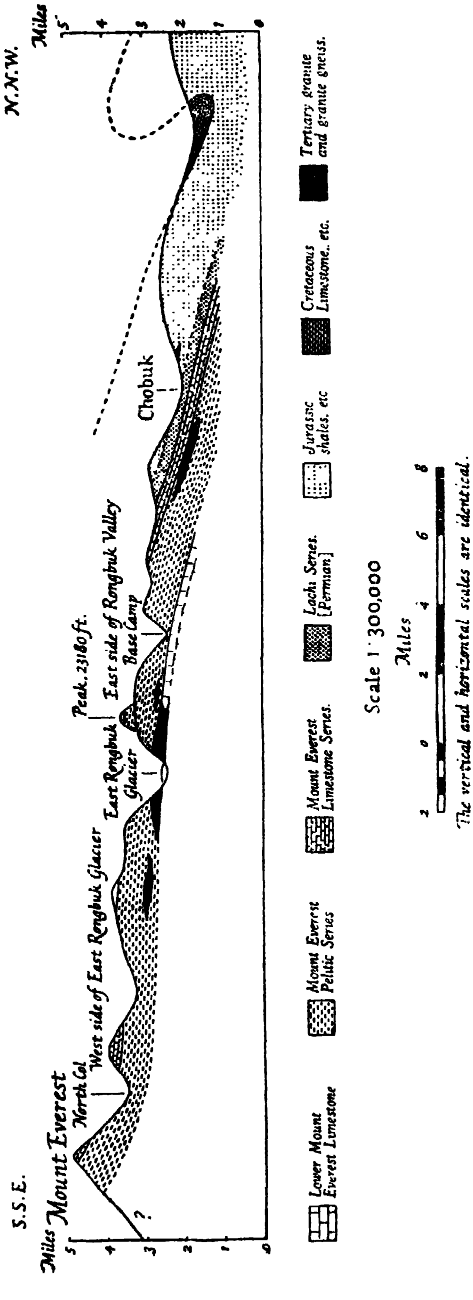


Fig. 2.—Geological Section through Mount Everest and Chobuk.

and from the east side of the Nionno Ri Range it can be traced for fifty miles into Lhonak. Here Garwood had found it in 1899, but had not been able to decide on its age (1903, pp. 287-8). Still further east there is the small exposure on the Lachi spur, while the limestone forming the lower part of Hayden's Dothak group, which I also visited, can unhesitatingly be ascribed to the Mount Everest limestone series. On the other hand, Hooker's thin blue limestone from Tso Lhamo, which Garwood tentatively correlated with the limestone he found in Lhonak, is certainly not the Mount Everest limestone but lies considerably above, and may well belong to the Tso Lhamo series of Triassic age.

The Mount Everest limestone has a characteristic lithology, usually showing bands a few millimetres thick which are rich in sand grains, while argillaceous material is normally absent. When weathered the arenaceous bands, being more resistant, stand out in relief (Plate 3). Under the microscope the calcareous material is sometimes seen to include a little dolomite in well-shaped crystals, and the sandy portion is seen to consist dominantly of quartz, fresh felspars and white mica. My colleague at Reading University, Miss P. S. Walder, has kindly examined the sand grains from two specimens of limestone collected at the entrance to the Rongbuk valley, and I am indebted to her for the following observations. After digesting with acid the residue consists of fairly well-graded sand without any clay fraction. In the sand from the first specimen the minerals present, in order of abundance, are : fresh felspar (including acid plagioclase, orthoclase and microcline), quartz, white mica, tourmaline and zircon. The usual size of the grains lies between 0·05 and 0·1 mm. but the mica flakes are on the whole decidedly larger, sometimes attaining 0·15 mm. As seen resting on the cleavage face the mica is also well rounded, whereas the other crystals are only moderately rounded. A count of 1,000 grains yielded the following frequency percentages : felspar (all types) 61·1 per cent., quartz 37·5 per cent., muscovite 0·8 per cent., tourmaline 0·4 per cent., zircon 0·1 per cent. The second example is so rich in sand grains that they remained cemented together after the solution of the carbonates and it was necessary to crush gently. The grain size and habit of the minerals is roughly the same and their frequencies are :—felspars (all types) 57·4 per cent., quartz 37·5 per cent., leucoxene 1·4 per cent., muscovite 0·6 per cent., tourmaline 0·6 per cent., zircon 0·3 per

cent., glauconite 0·1 per cent., garnet 0·1 per cent. A separation of heavy minerals also proved the presence of a little sphene. This assemblage indicates that the source was a granite area and the freshness of the felspars suggests arid or arctic conditions. The absence of clay material is surprising, and may be the result of wind transport, the lighter material having been carried beyond this area of deposition. Whatever the cause of this lithology, it is very characteristic of the Mount Everest limestone throughout the whole region from Mount Everest to the Chumbi valley.

V. THE AGES OF THE MOUNT EVEREST LIMESTONE AND THE MOUNT EVEREST PELITIC SERIES.

On Lachi the Mount Everest limestone apparently lies conformably below the Lachi series. Although fossils have not yet been found at this horizon elsewhere in the district, rocks which on lithological grounds are to be ascribed to the Lachi series are found overlying the Mount Everest limestone in the Chumbi valley (Hayden's Upper Dothak group) and north of Mount Everest. Since the Lachi beds are apparently found resting on the Mount Everest limestone over a distance of 150 miles, it seems safe to conclude that the Lachi beds pass downwards without any unconformity or thrust into the Mount Everest limestone series and that the Mount Everest limestone must be, in part at least, [Permo] Carboniferous in age. A few fossils in a bad state of preservation collected from the limestone at the entrance to the Rongbuk valley and from blocks of limestone in the north moraine of the Lhonak glacier do not conflict with this view.

Lying below the Mount Everest limestone in the Mount Everest region is a dominantly pelitic series which is probably about 4,000 feet thick. A few bands in this thick series are argillaceous sandstones and others are argillaceous limestones, but nevertheless pelitic material is strongly dominant. These rocks are frequently much injected by granite as sills and "*lits*". Odell sometimes called these rocks the gneissose biotite series, and sometimes the banded biotite gneiss. The extent to which the sedimentary material is injected by granite is variable; for instance it is considerable at the entrance to the Rongbuk valley and near the snout of the East Rongbuk glacier (Plate 4), but slight on the upper part of Mount Everest. It seems desirable to give a definite name

to the sedimentary part of these rocks and I have suggested the name Mount Everest Pelitic Series (1934, p. 334). These pelitic sediments were found underlying the Mount Everest limestone series not only in the Mount Everest neighbourhood, but also in the valley of the Phung Chu to the west of Sankar Ri and they are also admirably exposed in the Lashar and the Lhonak valleys (Map, Plate 5). Since the same sequence occurs at such widely separated localities it is reasonably certain that the Mount Everest pelitic series underlies conformably the Mount Everest limestone series, and that its age is Carboniferous or somewhat earlier.

In the Mount Everest region, lying apparently conformably below the Mount Everest pelitic series, there is a limestone horizon which Odell has called the Lower Calcareous Series. Limestones below pelites in the Phung Chu Valley where the village of Rongto is marked on the map (though no village can now be seen) may well be the same horizon but it becomes increasingly difficult with depth to disentangle the sedimentary sequence because of the increasing amount of granite injection.

VI. STRATIGRAPHICAL SUMMARY AND CONCLUSIONS.

From Mount Everest to north Sikkim a thick conformable series of sediments lying below the Jurassic and Cretaceous rocks of the Tibetan plateau, and often much metamorphosed and injected by granite has now been distinguished and in part mapped. First there is the Tso Lhamo series found by Auden in north Sikkim. Although the fossils which he collected have not yet been fully investigated they indicate a Triassic age for the beds. Below them is the Lachi series, an upper horizon of which has been determined by Dr. Muir-Wood from the brachiopod fauna as Upper Permian. Below this again is the Mount Everest limestone series consisting dominantly of arenaceous limestones of approximately Carboniferous or Permo-Carboniferous age. The rocks below the Mount Everest limestone, though usually much injected by granites, can be shown to consist of about 4,000 feet of dominantly pelitic sediments called the Mount Everest pelitic series. No fossils, not even unidentifiable traces, have yet been found in these rocks. Since they lie conformably below the Mount Everest limestone series they are probably Upper Palæozoic in age but they may extend downwards into the Lower Palæozoic. Finally there is

another dominantly calcareous horizon found in the Mount Everest region, but not with certainty elsewhere, which lies below the Mount Everest pelitic series.

The evidence for the essentially conformable nature of all these rocks is not merely conformity of dips but the fact that the same sequence is found in widely separated localities. It thus appears that in the Eastern Himalaya below the Permian there is a conforma-able series of sediments of the order of 6,000 feet in thickness and probably representing much of Palæozoic time. In Kumaun and Garhwal there was a period of erosion before the Permian deposits were laid down but there was apparently no break at this horizon in Upper Burma (La Touche, 1913). A break does not appear to occur in the Everest region and north Sikkim, although shallow-water conditions are indicated by the pebble beds in the Permian Lachi series. In the Eastern Himalaya continuous sedimentation in the Tethys Sea began early—probably in Carboniferous times, or before—and continued with no serious interruption until the Eocene. The sequence as so far determined, with rough estimates of the age and thickness of the newly defined groups, is :—

Kampa System. Cretaceous and Eocene.

Jurassic System.

Tso Lhamo Series, including a Triassic horizon.

Lachi Series (*ca.* 2,000 feet) including an Upper Permian horizon near the top.

Mount Everest Limestone Series (*ca.* 2,000 feet) Carboniferous.

Mount Everest Pelitic Series (*ca.* 4,000 feet) lying conformably below the Mount Everest limestone.

Lower Calcareous Series of the Mount Everest Region (? conformably below the above).

The Kongbu series, first distinguished by Hayden (1907, p. 20), lies below the Dothak group, the lower part of which belongs to the Mount Everest limestone series. Hayden was at first inclined to suggest a Palæozoic age for the Kongbu series, but later thought a Pre-Cambrian age more likely. It is probable that these rocks are the equivalent of the Mount Everest pelitic series, which are probably Upper Palæozoic in age.

As long ago as 1874 Mallet showed that in the Darjeeling district the Damuda series (approximately Permian in age) overlies Tertiary rocks; he thus proved extensive inversion although the facts were not then explained in this way. The descending

geological sequence in the Darjeeling district and Western Duars is probably to be interpreted as follows:

Nahan Group (Tertiary).
(Unconformity.)
Damuda Series (approximately Permian).
Baxa Series (present only in the Duars and age not proved).
Daling Series (age not proved).

From the evidence of its fossil flora the Damuda series is of slightly earlier age than the Lachi series. The Baxa series apparently immediately precedes the Damudas and is therefore probably of the same age as the Mount Everest limestone series. Thick dolomitic limestones are included in the Baxa series and this lithological similarity increases the likelihood of the series being the south-easterly continuation of the Mount Everest limestone. I have previously suggested the correlation of the Mount Everest pelitic series with the Dalings of the Darjeeling district (1934, p. 335). The latter are dominantly metamorphosed pelites, now largely chlorite schists. They have undergone low grade regional metamorphism and are at present very different in appearance from the Mount Everest pelitic series, which seems to have suffered a metamorphism about half way between regional and thermal in character. Nevertheless the Daling series was once a thick, dominantly argillaceous deposit of earlier age than the Damuda series and it is very possible, as Heron (Burrard, Hayden and Heron, 1934, p. 329) has also hinted that the Dalings are equivalent to the Mount Everest pelitic series.[1] The absence of the Baxa series in the Darjeeling district is no serious difficulty to this interpretation, since the Damudas are a terrestrial formation and a non-sequence, cutting out the limestone horizon, is a reasonable postulate. If these tentative correlations between the northern and southern flanks of the Eastern Himalaya be confirmed then we may hope in the near future to make definite progress in understanding the structures.

[1] It is interesting to note that Auden, and Heron (Auden, 1935, p. 162) have independently suggested that the pelitic component of the Darjeeling gneiss may be the same as the Daling series. With this view the few observations which I was able to make are in agreement. If the above correlations are correct this would mean that the sedimentary part of Darjeeling gneiss is the same as the Mount Everest pelitic series. *Lit-par-lit* injection as seen in the Mount Everest pelitic series, if taking place with somewhat greater cover and more migmatization would undoubtedly produce a series very similar to the Darjeeling gneiss. On the map (Plate 5) no distinction is made between the Darjeeling gneiss and the other highly metamorphosed rocks of the range. These include rocks of the Peninsular type (Wager, 1934, pp. 320-21).

VII. ACKNOWLEDGMENTS.

I wish to record my grateful thanks to Mr. Hugh Ruttledge, leader of the 1933 Mount Everest Expedition, who gave me all possible facilities for geological work. I wish also to thank many of the officers of the Geological Survey of India for the valuable information and help they gave me as I passed through Calcutta, both on the way out and on returning from the expedition, and especially I wish to thank Mr. J. B. Auden for many helpful discussions. Finally it is my pleasant duty to thank the Council of Reading University for granting me leave of absence to accompany the 1933 Mount Everest Expedition.

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IX. EXPLANATION OF PLATES.

PLATE 7. *Lachi spur from the east.* F_1—Locality of fossil corals, etc. F_2—Locality of Upper Permian fossils. F_4—Approximate locality of Auden's Triassic fossils. The junction between Mount Everest limestone and the underlying gneisses is to be seen on the left dipping north at 45°.

PLATE 8. *Mount Everest from 27,000 feet on the north-west ridge.* Mount Everest pelitic series in the foreground; the yellow slabs in the middle distance; the first and second steps (S 1 and S 2) on the skyline composed of massive, arenaceous limestone of the Mount Everest limestone series.

PLATE 9. Weathered fragment of *Mount Everest limestone,* three inches high, showing resistant bands which are dominantly arenaceous.

PLATE 10. Mount Everest pelitic series with a sill of light granite, 500 feet thick, fingering out into '*lits*'. North-east side of East Rongbuk Glacier near snout.

PLATE 11. *Geological Sketch Map of Drainage Areas of the Arun, Tista, and Ammu Chu.* The map is based on that illustrating the chapter on geology in the account of the 1933 Mount Everest Expedition (See Wager, 1934). The patterns adopted to show the various geological formations indicate the suggested correlations between the north and south sides of the range.

THE DUNGHAN LIMESTONE AND THE CRETACEOUS-EOCENE UNCONFORMITY IN NORTH-WEST INDIA. By E. S. PINFOLD, M.A., F.G.S., F.N.I. (With Plate 12.)

PREVIOUS WORK.

The presence of an important limestone at the base of the Eocene in Baluchistan was first recognised by Griesbach (*Mem. Geol. Sur. Ind.*, XVIII, Pt. 1, 1881, p. 22). His subdivisions of the Eocene in the Quetta region were, in descending order, as follows:—

Nummulitic Limestone,
Ranikot group,
Alveolina Limestone.

From Griesbach's description it is clear that his 'Alveolina limestone' was the Dunghan limestone of Oldham and later writers.

W. T. Blanford examined the same area shortly afterwards and found several points in which he differed from Griesbach's description (*Mem. Geol. Sur. Ind.*, XX, Pt. 2, 1883, p. 10). Blanford pointed out that in the absence of fossil evidence it was unsafe to use the term 'Ranikot' for Griesbach's middle subdivision and later work has shown that this criticism was justified; for this stage of the Eocene is now known as the Ghazij shales and is of Laki and not Ranikot age.

Blanford objected also to the use of the term 'Alveolina limestone' as the designation of an Eocene stage; for *Alveolina* is abundant at various levels of the Eocene and is not confined to any one horizon. Blanford went considerably beyond this, however, and denied the existence of any recognisable limestone at the base of the Eocene. He states (*idem*, p. 15): "There is, I believe, neither in the Bolan Pass nor near Quetta, any definite stage or subdivision that can be called the Alveolina limestone at the base of the Eocene. Alveolina-like nummulites are found throughout the system—there is no distinct band of limestone whether characterised by Alveolina or not, of sufficient importance to be distinguished as a primary subdivision or stage, either in the Bolan Pass or near Quetta, at the base of the Eocene system."

After examining the Quetta area, Blanford carried out a rapid reconnaissance survey southwards to the Bugti Hills, eastwards into Dera Ghazi Khan, and then northwards along the foothills of the Suleiman Range. Throughout all this region Blanford refers to the formation now known as the Dunghan limestone as a brown, sometimes calcareous, sandstone. Associated with this he recorded the occurrence of limestone breccias, a constant feature of the Dunghan limestone, and this is of assistance in correlating his succession with that of Griesbach and later workers. Blanford's failure to recognise the Dunghan limestone may have been responsible later for errors in correlation by La Touche and others.

R. D. Oldham next examined the Eocene of Baluchistan. He recognised the validity of Griesbach's subdivisions and gave them new local names, as follows (*Rec. Geol. Sur. Ind.*, XXIII, Pt. 3, 1890, p. 94):

	Feet.
Spintangi group	1,600
Ghazij shales	3,000
Dunghan limestone	2,000

The two lower formations are easily recognised over wide tracts in Baluchistan and Oldham's terms 'Dunghan limestone' and 'Ghazij shales' have been used by most later workers for the two main subdivisions of the Laki in that region. Oldham, like Griesbach, wrongly thought that the Ghazij shales were possibly of Ranikot age.

Southwards and eastwards into the Mari Hills, the Dunghan limestone thins out, and Oldham, in his description of the Mazar Drik and Des valley sections, included in the Dunghan stage certain lower fossiliferous shales and limestones. These contained a fauna which Oldham recognised correctly as definitely Cretaceous but, unfortunately, he mistook the orbitoids, which occur abundantly in these beds, for nummulites (*Rec. Geol. Sur. Ind.*, XXV, Pt. 1, 1892, p. 23). Because of this supposed admixture of Eocene with Cretaceous fossils, Oldham suggested as a strong possibility that the Dunghan group represented the gap between the Cretaceous and Eocene, and this found expression in the second edition of the *Manual of the Geology of India*, p. 291.

Shortly after Oldham's work in Baluchistan, T. D. La Touche examined the Sherani country in the northern foothills of the Suleiman Range and recognised the equivalents of the Dunghan lime-

stone and Ghazij shales. The former is a hard massive limestone, 250 feet thick, and rests on 'quartzose sandstones', 1,000 feet, and these on 'shales with minute nummulites and other fossils', 1,000 feet. La Touche here, like Oldham, mistook the orbitoids of the lowest formation for nummulites and this led him to include these Cretaceous beds with the Eocene in the table published with his description (*Rec. Geol. Sur. Ind.*, XXVI, Pt. 3, 1893, p. 82). In this region, the Eocene-Cretaceous junction is between the Dunghan limestone and the underlying sandstones; Vredenburg correlated these correctly with the Pab sandstones of Baluchistan.

Griesbach then re-examined the area between the Chappar Rift and Harnai to the north of the area mapped by Oldham, and his description (*Rec. Geol. Sur. Ind.*, XXVI, Pt. 4, 1893, p. 113) afforded him an opportunity of refuting part of Blanford's criticism and of correcting Oldham's suggestion regarding the supposed passage from the Cretaceous to the Eocene. Griesbach states that the 'lower nummulitic limestone' (the Dunghan limestone) forms a constant horizon over a considerable area and extends both into Khorassan and over the larger part of south-western Afghanistan. He considered Blanford's view that the limestone was a local facies only was quite untenable.

With reference to Oldham's collections, he writes (p. 116):—

"I have had an opportunity of viewing Mr. Oldham's 'anomalous' fauna since my last return to Calcutta, and in this I was advised by Dr. Noetling. It seems that all the cephalopods are true cretaceous forms, some of them in very fine preservation; they point to a lower than an upper cretaceous age of the beds. There were *no nummulites* in the collection from these fossil-bearing beds, but well-preserved *orbitolites*, which occurs in the cretaceous as well as in the tertiary systems. It seems, therefore, most probable to me, bearing in mind the fact that so far nothing but true tertiary forms with *nummulites* have been found in other localities in the Dunghan limestone, that the observation referred to is not complete."

Noetling's account of the fauna and stratigraphy of these beds is given in *Rec. Geol. Sur. Ind.*, XXVII, Pt. 4, 1894, p. 124, *Annual Report, G. S. I.*, 1898-1899, and in *Centralblatt*, 1903, p. 514. He shows that at Mazar Drik, the beds below a thin representative of the Dunghan limestone are *Cardita beaumonti* beds, Maestrichtian, Neocomian, and Jurassic. He still considered that there was some

evidence for a passage from the Cretaceous to the Tertiary in that three forms, *Ovula expansa*, *Ovula* sp., and *Nerinœa ganesha*, occur in both Cretaceous and Eocene beds and because there is no trace of a basal conglomerate or discordance of dip at the junction. At that time, however, he was not aware of Griesbach's error in correlating the Ghazij shales with the Ranikot of Sind. Although, as with most of the unconformities in this part of India, no basal conglomerate or discordance can be detected, it is now known that there is a considerable hiatus in the succession in Baluchistan and that the whole of the Ranikot is missing.

The Eocene of Baluchistan and Sind was later studied by Vredenburg, Tipper, Noetling, and others and it was found that the limestones of the Laki Range of Sind contained a different fauna from those of the Khirthar Range with which they had previously been correlated. The fauna of the Laki Range limestone is intermediate between the Ranikot and Khirthar faunas and Noetling named a new stage, the Laki, for rocks of this intermediate horizon (*Centralblatt*, 1905, pp. 135, 170). Vredenburg showed that the Dunghan limestone belonged to this stage. He re-examined the foraminifera from the Cretaceous of Mazar Drik and of La Touche's Sherani sections and showed that they belonged to several species of the genus *Orbitoides* (*Rec. Geol. Sur. Ind.*, XXXVI, Pt. 3, 1908, p. 171).

The most recent publications on the Eocene of Baluchistan are those of W. L. F. Nuttall (*Q. J. G. S.*, LXXXI, Pt. 3, 1925, p. 417, and *Rec. Geol. Sur. Ind.*, LIX, Pt. 1, 1926, p. 115). He confirmed Vredenburg's correlation of the Ghazij shales and Dunghan limestone with the Laki and he identified the following fossils from the lower formation :—

Nummulites atacicus,
Nummulites irregularis,
Assilina granulosa,
Alveolina lepidula,
Alveolina subpyrenaica,
Flosculina globosa,
Orbitolites complanata,
Opertorbitolites douvillei.

The assemblage is typical of the Laki stage. Nuttall, who was familiar with the Ranikot of Sind, states definitely that the Ranikot

is absent in the Bolan Pass and neighbouring region. He recognised the representative of the Dunghan limestone in the Suleiman foothills.

DISTRIBUTION AND CHARACTERISTICS.

The oil-shows of Khattan are mainly from the Dunghan limestone and this formation has therefore been of special interest to oil geologists, several of whom have mapped its outcrop from the type region through the Bugti Hills and Dera Ghazi Khan district to the borders of Waziristan. Throughout this wide tract, the formation is easily recognised as a hard, massive, well-bedded, and occasionally nodular limestone. In most of its outcrop, there is a single massive limestone of variable thickness up to several hundred feet. In some districts, more especially in the eastern part of the Bugti Hills, it comprises two or more thin beds of limestone separated by olive grey shales. The limestone everywhere contains abundant foraminifera but few other fossils; fish remains have been found in a black shale bed immediately above the top of the limestone in the Sham plain; calcareous algae occur frequently. The limestone is often brecciated, more especially at the top and bottom of the beds; Vredenburg considered that these breccias may pass laterally into true conglomerates and are usually associated with unconformity (*Rec. Geol. Sur. Ind.*, XXXIV, Pt. 3, 1906, p. 178), but it is doubtful if this view is generally applicable.

The Dunghan limestone is an extremely tough and resistant rock and occurring, as it does, below the comparatively soft Ghazij shales, Khirthar, and Siwalik, it is responsible everywhere for great dip slopes which form the flanks and summits of all the higher hills. Occasionally huge sheets of the limestone become detached and slide downwards and outwards over the adjacent shale beds and come to rest a considerable distance, sometimes extending to miles, from their normal position.

Throughout the Suleiman foothills, the Dunghan limestone rests on sandstones correlated with the Pab sandstones and these in turn on the Parh limestones or Belemnite Shales. There is exact conformity of dip and strike between these formations and little or no trace of a conglomerate at the base of the limestone; the presence of an important unconformity would not be recognisable were it not that the Ranikot and the uppermost members of the Cretaceous are missing.

CORRELATION.

Vredenburg regarded the Laki as equivalent to the lower part of the Lutetian (*idem*, p. 182), but Nuttall considers that the Laki should preferably be referred to the Lower Eocene, equivalent to part of the Thanetian and Ypresian. The faunal break between the Laki and Khirthar is very sharp and more pronounced than that between the Laki and the Ranikot.

The outcrop of the Dunghan limestone is almost continous from the Bolan Pass to the borders of Waziristan, a distance of over two hundred and fifty miles, and there is no difficulty about correlation throughout this long outcrop.

Correlation with the succession in Sind is less definite. Nuttall has shown that the Laki in Sind comprises:—

	Feet.
Laki limestone	200
Meting shale	95
Meting limestone	140
Laki laterite	25

This succession rests unconformably on Ranikot. It is clear that there is a considerable difference, both in lithology and thickness, between the Sind and Baluchistan sections. The soft, white, nodular limestones of the Sind Laki are of entirely different type from the hard dark grey brecciated Dunghan limestone and there is no representative in Sind of the thick Ghazij shales. Nuttall groups the Meting limestone with Dunghan in his table showing the distribution of the foraminifera, and the two formations are similar in the paucity of other fossils; but he does not attempt direct correlation between the two regions.

There is a similar difficulty in attempting to correlate the succession in the Suleiman foothills with that of Waziristan, the Kohat district, and the northern Punjab. La Touche observed that the Dunghan limestone disappears from the succession to the north and is absent in the lattitude of the Zao valley on the border of Waziristan and this has been confirmed by later work. He considered this disappearance as being due to thinning out caused by variations in conditions of deposition and suggested that Waziristan, the region in which the north and south strike of the Suleiman Range gives place to the east and west strike of the Himalayan folding, was possibly a land barrier throughout the greater part of

the Lower Tertiary (*Rec. Geol. Sur. Ind.*, XXVI, Pt. 3, 1893, p. 93). It now seems probable that the disappearance of the Dunghan limestone is due to unconformity and overlap at the junction of the Tertiary with older rocks. La Touche pointed out that whilst correlation of the Sherani succession with that of Baluchistan was simple, no correlation could be made at that time with the Eocene of the Kohat district or the Punjab.

Correlation of the Eocene of the Sherani country and Suleiman foothills with that of the North-West Frontier Province and the north Punjab is by no means easy and is possible only by the occurrence of the larger foraminifera. The Ranikot, Laki, and Khirthar faunas are quite different and there is rarely any difficulty in attributing any marine Eocene deposit to its rightful place in the sequence. Lithologically, however, the deposits east and north-east of Waziristan show considerable variation in contrast with the extraordinary constancy in the Sherani-Baluchistan region. The differences suggest that there were two separate basins of deposition with the Waziristan ridge as the barrier between them. In some parts of Waziristan, not only the Laki but the whole of the Eocene and a large part of the Upper Tertiary are absent and Upper Siwalik rocks rest directly on belemnite shales. In other sections, *e.g.*, north of Jandola in South Waziristan, the Laki is represented only by a small thickness of red and grey shales with an estuarine fauna; these are similar to the upper part of the Ghazij shales in the Suleiman foothills. The Dunghan limestone is absent in Waziristan. Ranikot shales with limestone bands, sometimes with a rich development of corals, occur in North Waziristan and in places attain a considerable thickness; these form the only important outcrop of Eocene rocks in this region. In North Waziristan the Laki entirely disappears and Ranikot beds are overlain by a few feet only of Khirthar limestone.

The most recent work in Waziristan has been that of Dr. A. L. Coulson and descriptions of his results are given in the General Reports for 1936 and 1937, *Rec. Geol. Sur. Ind.*, LXXII, Pt. 1, p. 71 and LXXIII, Pt. 1, p. 83.

Lt.-Col. L. M. Davies established the presence of Ranikot beds at Thal (*Quart. Jour. Geol. Soc. Lond.*, LXXXIII, pp. 260-290) and at Hangu (*Pal. Ind.*, N. S., Vol. XV, Pt. 1). The thin limestones overlying the Ranikot at Thal are of Khirthar age and no fossiliferous Laki has yet been described from the area west of Kohat.

East of Kohat, the same worker has shown that the succession in the Shekhan Nullah comprises a series of fossiliferous limestones and shales of Khirthar age overlying the Shekhan limestone, which is Laki. To the south (Shadi Khel) and east (Tarkhobi-Panoba anticlinal), the Shekhan imestone is underlain by a thick shale series containing *Assilina granulosa* and *Nummulites irregularis* and these shales rest in turn on a massive limestone of Ranikot age.

Further east, in the Kala Chitta Hills of the north Punjab, the Laki is again much reduced and consists mainly of massive grey limestones with a few thin shale beds, the whole being only 200 to 300 feet in thickness. These rest on a considerably greater thickness of Ranikot limestones and shales.

In the Salt Range the Laki comprises :—

	Feet.
Bhadrar beds	0-300
Sakesar limestone	200-500
Nammal limestones and shales	100-400

Nummulites irregularis, which occurs near the base of the Ghazij shales in Baluchistan, is abundant in the lower part of the Nammal stage in the Salt Range. The Laki is underlain by Ranikot limestones and shales with a ferruginous pisolite at the base. Mr. E. R. Gee, who has recently surveyed the Salt Range in considerable detail, states (*Trans. Min. Geol. Met. Inst. Ind.*, XXXIII, Pt. 3, 1938, p. 270) that the base of the Tertiary rests with pronounced unconformity on older rocks and that the Upper Cretaceous is everywhere absent. Dr. Cotter has also stressed the absence of the *Cardita beaumonti* zone in this region (*Mem. Geol. Sur. Ind.*, LV, Pt. 2, 1933, p. 91). Thus the suggestion by Blanford (*idem*, XVII, 1880, p. 36) and others that a passage from Cretaceous to Tertiary possibly occurred in the Salt Range, is now known to be entirely without foundation.

It will be observed that the Laki of these northern sections is quite different from the Ghazij-shale-Dunghan-limestone sequence, which is constant throughout such a wide outcrop in Baluchistan. In the Salt Range and Kohat, there is no limestone at the base of the Laki corresponding to the Dunghan limestone and there is some evidence that the Laki of this northern province should be correlated with the upper part of the Ghazij shales of the Suleiman foothills; for a considerable distance north and south of Drug, these beds consist of nodular limestones and shales crowded with

Nummulites atacicus and *Assilina granulosa* and it is with these limestones, rather than with the Dunghan limestone, that the Laki of the northern province is most nearly allied. The presence of unconformity between the Laki and Ranikot in the Salt Range was postulated by Davies and Pinfold (*Pal. Ind.*, N. S., XXIV, Mem. No. 1, 1937, p. 13).

THE FLYSCH REGION.

To the west and north-west of Baluchistan, the Tertiary succession of Sind gives place to a monotonous series of grey shales and clays with occasional harder bands; Vredenburg has compared these beds with the Flysch of the Alpine region in Europe. These rocks are known as the Khojak shales or Mekran system. They are sparsely fossiliferous but are usually accepted as being mainly of Oligocene age; it is possible, however, that they include Eocene and older rocks.

The following appears in a Tri-monthly note, *Rec. Geol. Sur. Ind.*, XXVII, Pt. 3, 1894, p. 109: "One of the most interesting facts elucidated, consists in the establishment of the age of the Khojak Shales and their eastern prolongation into the Zhob, which by their fossil contents are now known to be intermediate in age between Upper Cretaceous and Upper Eocene, and to form a more or less continuous facies closely associated with a variety of igneous rocks." No later mention or confirmation of these observations has been traced; so far as is known, this is the only claim to a passage from Cretaceous to Eocene which has not been refuted by later work. This question is being further investigated by Mr. E. R. Gee.

SUMMARY.

(1) The Dunghan limestone is the lowest subdivision of the Laki in the region between the Bolan Pass and the Suleiman foothills.

(2) The Laki of this tract differs in thickness and lithological sequence from that of Sind and from that of the Kohat district and the north-west Punjab; direct correlation is not possible and there is some evidence for the existence in Laki times of separate areas of deposition. In the northern area, the Laki beds are equivalent to the upper part of the Ghazij shales; the Dunghan limestone is absent.

(3) The Dunghan limestone rests with unconformity on Cretaceous beds; the old conception that the Dunghan subdivision contained a passage fauna between the Cretaceous and Eocene has long been recognised as erroneous.

MAP.

The map accompanying this paper is a continuation northwards of the useful map of Sind and Baluchistan published by Vredenburg in *Rec. Geol. Sur. Ind.*, XXXVIII, Pt. 3, 1909, Pl. 12. Vredenburg represented the Nari as resting directly on the Ghazij shales in the neighbourhood of Fort Munro and at the northern edge of his map, but more recent surveys than were available to him have shown that the Lower Khirthar and Lower Middle Khirthar are developed characteristically in this region.

The following classification of the Eocene has been used in preparing the map:—

Khirthar.—Lower Middle Khirthar includes all the Khirthar down to and including a prominent white limestone band, about 50 feet thick, crowded with *Discocyclina* of several species. This limestone can be traced continuously throughout the region.

Lower Khirthar includes the variegated shales, white cherty limestone, and alabaster shales. The white limestone of this division occurs also in the neighbourhood of Jandola in South Waziristan; this outcrop, however, is too narrow to be shown on a small scale map.

Laki.—The subdivision of the Khirthar follows Nuttall's classification, *Rec. Geol. Sur. Ind.*, LIX, Pt. 1, 1926, p. 118, but the thick limestone with *Nummulites atacicus* which he placed in the Lower Khirthar has been included with the Laki; it is only in the neighbourhood of Drug that this limestone attains the thickness quoted by Nuttall; in other areas it is represented by alternations of white nodular limestones with *N. atacicus* and olive shales containing abundant *Assilina granulosa*. In the northern part of the area, this horizon is absent or is represented by red and grey clays with an estuarine fauna. The Dunghan limestone is typically developed throughout most of the area, but is absent in Waziristan.

ACKNOWLEDGMENT.

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ON TWO SMALL COLLECTIONS OF FOSSIL FISH-REMAINS FROM BALASORE, ORISSA. By SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plate 13.)*

In May 1937, Dr. M. R. Sahni, Palaeontologist, Geological Survey of India, handed over to me a small collection of fossil specimens obtained by Mr. N. H. Cour-Palais, Assistant Engineer, Bengal Nagpur Railway, from a tube well boring between 100 and 200 feet below ground level at Balasore. In sending the material Mr. Cour-Palais had remarked that "similar fossils have been found in several other tube wells here and even at Baripada, 40 miles from the sea, Mayurbhanj State". Later, in September 1937, Mr. W. D. West, Assistant Director, Geological Survey of India, sent more material of similar fish-remains, which had been presented to the Survey by Mr. J. G. Gilson, Secretary, Balasore Technical School, Balasore. Mr. Gilson obtained this material from "white sand deposit between 125 and 175 feet below ground level in a well at Soro, Balasore District".

Fossil fish-remains in both the collections are of a very fragmentary nature and comprise teeth of sharks and rays, bits of tail-spines of rays, portions of pectoral and dorsal spines of Cat-fishes and teeth of certain Scombrioid fishes. These remains are, however, fairly well preserved and indicate a Tertiary age of the beds in which they lay entombed.

There is a great variety of shark teeth in the material under report and it has been possible to assign them to *Carchariolamna* gen. nov., *Oxyrhina* Ag., *Scoliodon* M. & H., *Priodon* M. & H., *Hyprion* M. & H. and *Apriodon* Gill. Both the teeth and tail-spines of rays are referred to the family Myliobatidae. The Siluroid remains probably belong to the genus *Arius* Cuv. & Val., but the spines are very fragmentary for any specific determination. Some of the Scombrioid teeth probably belong to the genus *Trichiurus* Linn., while in the case of 2 isolated short, rounded and hollow teeth it has not been possible to determine them even generically, though they show Scombrioid affinities.

* Published with the permission of the Director, Zoological Survey of India.

With the exception of *Carchariolamna*, all the other genera, to which the material has been assigned, are found in a living state at the present day. The new genus, as its name implies, is closely related to *Lamna* Cuvier, a genus ranging from the Upper Cretaceous to the present day, but the teeth, on the characters of which it is based, possess delicately serrated edges. It is thus also related to *Carcharoides* Ameghino, a genus so far known only from the Eocene formations of South America and Australia, but can be readily distinguished from Ameghino's form by its less developed lateral denticles, form of teeth and the nature of their serrated edges. Taking into consideration the known geological history of the various genera represented in the collections, especially of the genus *Hypoprion*, it may be inferred that the boring at Balasore may have traversed the various strata as far down as the Middle Tertiary formations.

Concerning the probable age of the rocks met with in the Balasore borings, Dr. M. R. Sahni has favoured me with the following note dealing with other occurrences of Tertiary rocks in borings, etc., in Mayurbhanj State :--

"At Molia, 2 miles south of Baripada, are exposed in the bed of the Barabalang river, yellowish and yellowish-brown limestones, very rich in remains of *Ostrea*. Dr. Pilgrim who examined a few of them considered them related to certain Tertiary forms, namely, *Ostrea multicostata* Deshayes, from the upper part of the Eocene of the Paris basin, and *O. torresi* Phillipi, from the *Magellania* beds of Patagonia, which are probably Oligocene in age. It was further thought that these specimens are related to an undescribed species of *Ostrea* found in the upper Nari beds of Baluchistan, which are probably Oligocene in age. "The age of these beds is therefore Eocene or Oligocene on this evidence (P. N. Bose. *Rec. Geol. Surv. Ind.*, XXXI, Pt. 3, p. 167).

"In the Tertiary deposits at Baripada, a boring was put down in a well at the traveller's bungalow and was carried down to a depth of 163 ft. (including 40 ft., the depth of the well). "At a depth of 123 ft. below the surface occur limestones with fragment of an *Ostrea* (?).

"Unfortunately, the fossils yielded by the boring are generally indeterminable. The limestone at 142 ft. from the surface is crowded with *Amphistegina*. Dr. Pilgrim observes: 'Although it is true that *Amphistegina* was very much more abundant in the Miocene, still it is found in the seas of today, most commonly up to a depth of 30 fathoms. But added to the testimony of the *Ostrea* (*Rec. Geol. Surv. India*, XXXI, Pt. 3, p. 167), it strengthens the probability that we are dealing with a marine deposit which is at all events as old as Miocene' (G. Pilgrim in P. N. Bose, *Rec. Geol. Surv. Ind.*, XXXIV, Pt. 1, p. 43).

"According to this evidence, then, the beds were thought to be Miocene or older. "But Dr. Tipper who re-examined these fossils has thrown doubt upon their identification. "He considers that the specimens collected by Mr. P. N. Bose

and identified by Dr. Pilgrim are not *Amphistegina* but *Rotalia*. This *Rotalia* is related to the recent *R. orbicularis* d'Orb from the Arabian Sea and is perhaps allied to *R. beccarii*, Linn.

"Now the genus *Rotalia* is known from the Jurassic to the present day, hence it is impossible to draw any conclusion with regard to the age of the deposit (G. H. Tipper, *Rec. Geol. Surv. Ind.*, XXXIV, p. 135).

"The evidence on the whole indicates that the beds are probably not so old as they were first thought to be.

"Certain specimens of *Ostrea* found in the yellowish and yellowish-brown limestones at Molia, were examined by Mr. Eames and identified as *Ostrea (Crassostea) gajensis*. This species is recorded by Vredenburg from the upper Gaj of N. W. India, and also from Burma.

"Specimens of this species from the Burma Tertiaries are all of Lower Miocene age.

"It, therefore, appears very probable that these Baripada limestones are of Gaj (Lower Miocene) age (F. E. Eames, *Rec. Geol. Surv. Ind.*, LXXI, Pt. 2, p. 150).

"The writer (M. R. Sahni, *Rec. Geol. Surv. Ind.*, LXVIII, Pt. 4, p. 419) examined a few lamellibranch specimens collected (not *in situ*) from the foreshore at Puri and compared them with the Miocene form of *Paphia gregaria* (Partsch), thus postulating the probable underground occurrence of Miocene rocks near Puri. The matrix infilling these specimens is identical to that in the Baripada boring, previously mentioned and the Balasore boring.

"In conclusion I may say that, considering the fresh appearance of the Balasore fossils and the greyish clay matrix which appear to be identical with that found in the Baripada boring (*vide ante*), the rocks met with in the Balasore boring are not older than Miocene and are probably younger."

The entire material is preserved in the collection of the Geological Survey of India (Mr. Cour-Palais's specimens are numbered K 40/275—K 40/281, and G. S. I. Types 16646-16651, and Mr. Gilson's K 40/311--K 40/316). Besides the specimens actually reported upon in this article, there are few small bits which I have left indetermined. Owing to the fragmentary nature of the material and a large number of fossil sharks described on insufficient data, I have not attempted a specific determination of the majority of the fossil teeth. In some cases, it has not been possible even to assign a generic position.

I am grateful to Dr. A. M. Heron, Director, Geological Survey of India, through whose kindness I have been afforded an opportunity to report on the Balasore fossil fish-remains. My sincere thanks are also due to Dr. M. R. Sahni for his valuable note on the probable age of the rocks, and for his suggestions. To Dr. E. I. White I am greatly indebted for his helpful criticism and suggestions in connection with some of my determinations.

Class ELASMOBRANCHII.

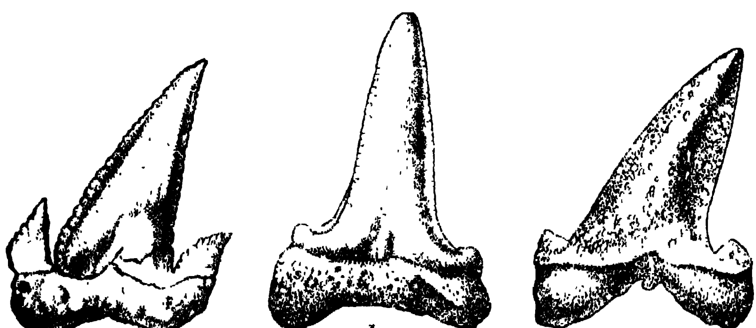
Sub-Class SELACHII.

Order EUSELACHII.

Family *LAMNIDAE*.

Genus CARCHARIOLAMNA nov.

Diagnosis.—The new genus *Carchariolamna* (Plate 13, figs. 1-4; text-fig. 1 *b*) is proposed for Selachian teeth from a boring at Balasore, having the dual characters of *Lamna* Cuvier (text-fig. 1 *c*) and *Carcharodon* Müller & Henle. It bears a close affinity with the Eocene genus *Carcharoides* Ameghino (text-fig. 1 *a*), from which it is distinguished by the less developed or totally absent lateral denticles, very finely serrated edges, and an almost erect and blunt crown.



TEXT-FIG. 1.—Fossil teeth of *Carcharoides* Ameghino, *Carchariolamna* gen. nov., and *Lamna* Cuvier.

a. Carcharoides totuserratus Ameghino (after Chapman); *b. Carchariolamna heroni* gen. *et* sp. nov.; *c. Lamna* sp. from the Salt Range (after Hora).

The teeth are solid throughout and are, therefore, referrable to the family Lamnidae and not to the Carcharinidae, in which the teeth are invariably hollow.

Geno-type.—*Carchariolamna heroni* gen. *et* sp. nov.

Carchariolamna heroni gen. *et* sp. nov.

(Plate 13, figs. 1-4; text-fig. 1 *b*.)

Material.—Specimens G. S. I. Type Nos. 16646—16651 (six isolated teeth or fragments of teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

Description of the Holotype.—G. S. I. Type No. 16646, (Plate 13, fig. 1; text-fig. 1 *b*).—The tooth is of a moderate size and is very much like that of *Lamna* in its general facies. The base is broad and strong, and somewhat arched. The apical part is strong and erect, and tapers to the apex which is blunt. The external face of the crown is depressed and convex; it is provided with a weak median sulcus extending for a short distance from the junction of the base upwards. The internal face is also depressed, but is concave. The lateral cusps are small, blunt, and almost incipient. The edges of the crown are compressed, thin and very delicately serrated; the serrations do not extend to the base of the crown. The surface of the crown and the lateral denticles is smooth.

Dimensions.—Total length, 18 mm. (crown, 14·4 mm.; base, 3·6 mm.). Width of crown at base, not including cusps, 8·5 mm.; thickness, 3·9 mm.

Description of co-types.—The remaining specimens in the collection vary considerably from the type, but probably these variations are correlated with the different positions of the respective teeth in the jaws. In one specimen, G. S. I. Type No. 16647, (Plate 13, fig. 2), 11·7 mm. in total length, the base is considerably broader than the height of the crown. The lateral cusps are totally absent. The crown is delicately serrated in its upper half, while in the basal portion the edge is slightly crenulated. In another specimen, G. S. I. Type No. 16648, (Plate 13, fig. 3), 14·8 mm. in total length, the base is stout and narrow; the lateral denticles are absent and the edges of the crown are serrated only in the upper half. In a partially damaged tooth, G. S. I. Type No. 16649, (Plate 13, fig. 4), 12·9 mm. in total length, the lateral edges of the crown are serrated throughout and there are no lateral denticles. One broken tooth, G. S. I. Type No. 16650, was sectioned just above the base (Plate 13, fig. 4*a*) and it was found to be solid. In another tooth, G. S. I. Type No. 16651, in which the upper half of the crown is damaged, the lateral edges are serrated almost to the base; the

lateral denticles, though minute, are present and the base is akin to that of the holotype.

Affinities.—Relying on Zittel's (1932, p. 77) characterization of the various genera I referred the above material to ***Carcharoides*** Ameghino, but as this genus is so far known only from the Lower Tertiary formations of South America and Australia, and as the probability is that the Balasore rocks are younger, Dr. M. R. Sahni wished me to look into the identification of this material more closely. Unfortunately Ameghino's (1906) original description is not available in Calcutta, so photographs of the 4 teeth reproduced here were sent to the British Museum for determination. In reply Dr. E. I. White, in his letter dated the 12th July, 1938, wrote as follows :—

> "From the photographs I do not believe that your specimens have anything to do with the genus *Carcharoides*, of which both the known species have triangular teeth and very well developed lateral denticles. To judge from the photographs I should say that your specimens are the teeth of a species of *Carcharinus*, in which, as you know, incipient lateral denticles are not infrequently developed."

Dr. White also directed my attention to Chapman's paper in which both the known species of *Carcharoides* are described and figured. After consulting Chapman's article (1917) and finding the serrations on the edges of the Balasore teeth quite different from those associated with the teeth of *Carcharinus* (=***Prionodon***), I sent the type-specimen to Dr. White with the permission of the Director, Geological Survey of India. After an examination of the tooth, Dr. White wrote as follows in his letter dated the 26th July, 1938 :—

> "I must confess that I am rather puzzled by this particular tooth, as it really does not fit in properly with any of the forms with which I am familiar. I did not realise from your photographs that it was so worn, and that therefore the denticles might have been larger. It certainly does not seem to belong to any known species of Carcharinid, but, on the other hand, the form of the crown on the denticles is certainly different from that of the two species of *Carcharoides*, in which the crown is always triangular, as in true Lamnids, and the denticles are very large and the base correspondingly broad."

For placing the teeth correctly in either Lamnidae or Carcharinidae, Dr. White suggested to me to break a tooth in half and noted "Lamnid teeth are solid throughout, whereas Carcharinid teeth are usually hollow". In accordance with Dr. White's suggestion I sectioned one of the teeth (Plate 13, fig. 4 *a*) and found it to be solid. Other fragments of teeth in the collection were also found

to be solid. I sent the section and one broken tooth to Dr. White with my letter of the 2nd August, 1938, in which I made the following observations :—

"In view of this (solid nature of teeth) and their general form they may be referred to the Lamnidae, but as they differ from *Lamna* and *Carcharoides* in the nature of their lateral edges I think it is desirable to refer them to a new genus. The other shark teeth from the same tube-well boring show Miocene affinities, and as *Carcharoides* is definitely an Eocene genus I think it would be advisable on this consideration also to keep them in a distinct genus. In several respects the new genus will be intermediate between *Carcharoides* and *Lamna*, in fact it will indicate the evolution of the *Lamna*-type and the *Oxyrhina*-type of teeth from the *Carcharoides*-type of teeth."

To this Dr. White in his letter, dated the 8th August, 1938, replied that "It does seem that the serrated teeth are solid ; indeed I took the liberty of cracking the one sectioned across the base to make certain that this part was also without a hollow".

In the above correspondence details are given of the probable affinities of the new genus, and the reasons why on morphological and stratigraphical grounds it has been found necessary to recognise it as a distinct genus. In the incipient development or total absence of the lateral denticles the new genus corresponds with *Oxyrhina* Ag. (Plate 13, figs. 5-6, text-fig. 2), but in the latter, as in *Lamna*, the lateral edges are smooth.

The presence of well-developed lateral denticles is a primitive feature in Selachian teeth (*vide* Smith, 1937) and therefore it would appear that among the Lamnidae *Carcharoides*, an extinct genus, represents the least specialized form. From *Carcharoides*, by the reduction in the size of the lateral denticles and the progressive reduction in the serrations on the edges, we can derive *Carchario-lamna*, another extinct genus. By a further modification of the edges of the crown, which now became smooth, we get the two living genera *Lamna* and *Oxyrhina*, the former with lateral denticles and the latter without them. The discovery of the new genus has thus enabled to bridge over the gulf between *Carcharoides* on the one hand, and *Lamna* and *Oxyrhina* on the other.

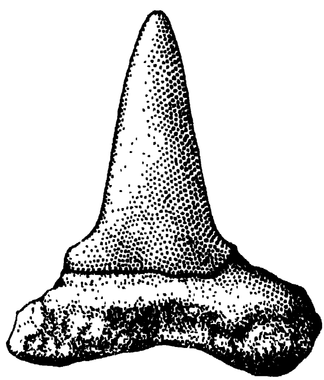
The new species of fossil sharks is associated with the name of Dr. A. M. Heron, Director, Geological Survey of India, in slight recognition of the manifold courtesies received by the author in his work on fossil material belonging to his department.

Genus OXYRHINA Agassiz.

(Plate 13, figs. 5-6; text-fig. 2.)

Material.—Specimens Nos. K 40/275*a* and K 40/275*b* (two isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The two isolated teeth, which I have referred to *Oxyrhina*, are similar to those of *Lamna* but lack the lateral denticles. In one of the specimens, K 40/275*b*, (Plate 13, fig. 6), however, there are indications of minute lateral denticles. The base is broad and bilobed, and the cusp, which is smooth, is slightly curved inwards. The crown is placed vertically above the base and the apex is not very sharp. In general facies, these teeth, except for the smooth edges, correspond very closely with those of *Carchariolamna.*



TEXT-FIG. 2.—Fossil tooth of *Oxyrhina* Agassiz. ×4.

According to Zittel (1932, p. 77), *Oxyrhina* ranges from the Cretaceous to the recent times. Two species of the genus, *O. glaucus* M. & H. and *O. güntheri* (Murray), are known to occur in the seas of India at the present day.

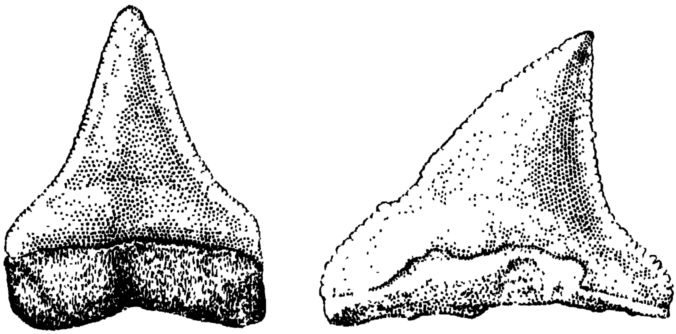
Family *CARCHARINIDAE.*

Genus PRIONODON Müller & Henle.

(Plate 13, figs. 7-10; text-fig. 3.)

Material.—Specimens Nos. K 40/275*c* to K 40/275*g* (eight isolated teeth and fragments), collected by Mr. N. H. Cour-Palais at Balasore), and K 40/311 (four isolated teeth), collected by Mr. J. G. Gilson at Soro.

The fishes of the genus *Prionodon* are the dominant sharks of the present day and are represented by a large number of living species. Numerous fossil species have been described from the Eocene and later formations.



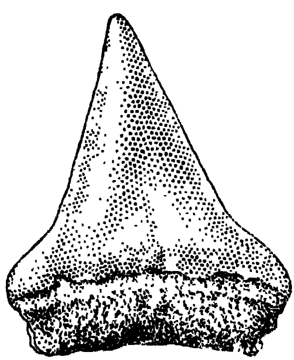
TEXT-FIG. 3.—Two fossil teeth of *Prionodon* Müller & Henle. ×3.

The teeth of *Prionodon* are compressed, subtriangular and provided with a single cusp, the edges of which are serrated to the apex. The teeth vary in form and size according to their respective positions in the jaws.

Besides the material enumerated above, there are several unsatisfactory fragments of *Prionodon* teeth among the indetermined lot.

Genus SCOLIODON Müller & Henle.

(Plate 13, figs. 11-14; text-fig. 4.)



TEXT-FIG. 4.—Fossil tooth of *Scoliodon* Müller & Henle. ×4.

Material.—Specimens Nos. K 40/275*h*—275*k* (four isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The four teeth referred to the genus *Scoliodon* possess smooth edges. The base is broad but not swollen. The cusp is almost erect, triangular and sharply pointed.

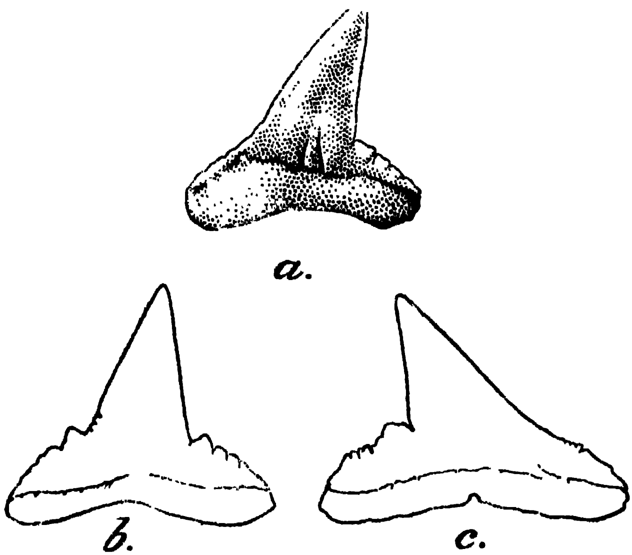
Scoliodon is a widely distributed genus of the present-day sharks and is represented by about a dozen species. Its fossil remains date as far back as the Lower Eocene.

Genus HYPOPRION Müller & Henle.

(Plate 13, fig. 15; text-figs. 5*a*, *b*, *c*.)

Material.—Specimen No. K 40/275*l* (one isolated tooth). Collected by Mr. N. H. Cour-Palais at Balasore.

There is one, relatively small, isolated tooth in which the cusp



TEXT-FIG. 5.—Teeth of *Hypoprion* Müller & Henle.

a. Fossil tooth from Balasore. ×4; *b.* Sixth upper tooth of *H. macloti* Müll. & Henle. ×12; *c.* Third upper tooth of same. ×10.

Length of specimen including caudal 492 mm.

is oblique with smooth edges except at the base where it is coarsely serrated on one side and crenulated on the other. Similar teeth are usually characteristic of the upper dentition of *Hypoprion* M. & H.

Two living species of the genus are found in the seas of India—*H. macloti* M. & H. and *H. hemidon* M. & H. I have examined the teeth of the former and found considerable variation in regard to the number of denticulations on the two sides of the base (text-fig. 5 *b* and *c*).

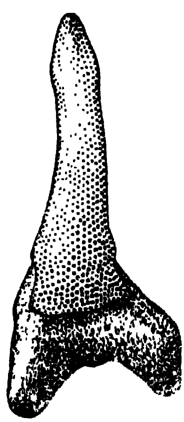
The genus *Hypoprion* dates back to the Miocene. So far as I am aware no earlier record of the genus is known.

Genus APRIONODON Gill.

(Plate 13, figs. 16-20; text-fig. 6.)

Material.—Specimens Nos. K 40/275*m*—275*q* (five isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.

The five isolated teeth referred to the genus *Aprionodon* vary from one another in shape and size, presumably owing to their different positions in the jaws. They are compressed with narrow inwardly curved cusps which are smooth along the edges. Their bases, where preserved, are fairly broad and bilobed. The cusps are lanceolate towards their terminations and are devoid of any ornamentation.



TEXT-FIG. 6.—Fossil tooth of *Aprionodon* Gill. ×4.

Among the three living species assigned by Garman (1913, pp. 117-119) to *Aprionodon* the teeth are stated to be lanceolate in *A. acutidens* (Rüpp.). The range of distribution of *A. acutidens* is given as "Indian Ocean and Archipelago; Red Sea". Unfortunately

there is no specimen of the species in the collection of the Indian Museum, but it seems probable that the fossil teeth from Balasore are either referrable to this species or to some other allied form.

Aprionodon is known from the Tertiary formations to the recent times.

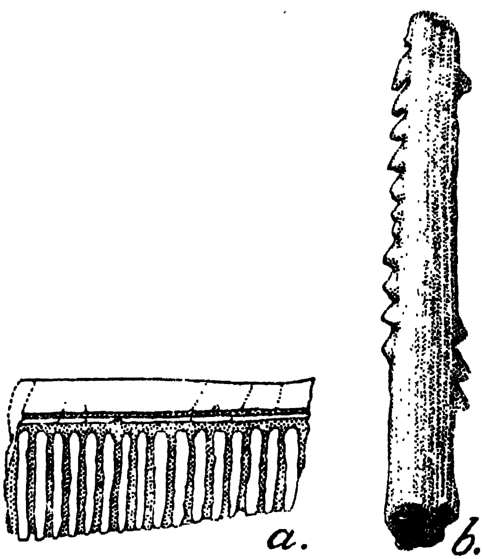
Order BATOIDEI.

Family *MYLIOBATIDAE.*

Genus MYLIOBATUS Cuvier.

(Plate 13, figs. 21-24 (teeth); figs. 25 (spine); text-figs. 7*a*, *b*.)

Material: Teeth.—Specimen Nos. K 40/275*r* (one fragment); K 40/277*a*—277*d* (four fragments), K 40/280 (one fragment), collected by Mr. N. H. Cour-Palais at Balasore; and K 40/314 (five fragments), collected by Mr. J. G. Gilson at Soro.



TEXT-FIG. 7.—*Myliobatid* fish-remains.
a. Fragment of isolated centre-tooth of *Myliobatus* Cuvier. ×3; *b.* Fragment of tail-spine. ×1½.

Spines.—Specimen Nos. K 40/281 (a portion of a spine), collected by Mr. N. H. Cour-Palais at Balasore; and K 40/315 (a small

fragment with 3 teeth on one side only), collected by Mr. J. G Gilson at Soro.

The Myliobatid remains are very unsatisfactory for a specific determination, but there seems hardly any doubt that they belong to the genus *Myliobatus* Cuvier. All the specimens of teeth are fragments of isolated centre-teeth. Though the tail-spines of the Myliobatid rays are of frequent occurrence in the Tertiary rocks they have not been found to exhibit any definite features of diagnostic value. The two fragments of tail-spines represented in the collections, owing to their association with undoubted Myliobatid teeth, possibly are referrable to the genus *Myliobatus.*

Though as a family the Myliobatidae date back to the Cretaceous period, most of the surviving genera, such as *Myliobatus* Cuvier, *Rhinoptera* Müller, *Actiobatus* M. & H., etc., are well represented in the Tertiary formations by isolated teeth and spines.

Class PISCES.

Sub-Class TELEOSTEI.

Super-Order OSTARIOPHYSI.

Order SILUROIDEA.

Family *ARIIDAE.*

Genus ARIUS Cuvier.

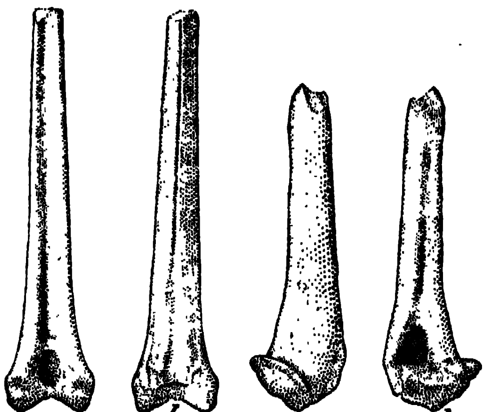
(Plate 13, figs. 26-29; text-figs. 8*a, b, c, d.*)

Material.—Specimens Nos. K 40/279 *a, b* (two fragments of basal portions of spines; dorsal spine and left pectoral spine). Collected by Mr. N. H. Cour-Palais at Balasore.

In both the fragments the preserved basal portions of the shafts are without any serrations, but this is not unusual even among some of the living members of the genus *Arius,* in some of which the serrations are present only near the terminal parts of the spines. From the nature of the articular surfaces of the two fragments it is possible to determine them as dorsal and pectoral spines respectively.

The dorsal spine, K 40/279 *a,* (pl. 13, figs. 26-27; text-fig. 8, *a* and *b*) is grooved along the posterior border; it is flattened

anteriorly and grooved at the proximal end. The spine is compressed from side to side and ornamented with faintly marked longitudinal ridges.



a. b. c. d.

TEXT-FIG. 8.—Fragments of dorsal and pectoral spines of a Siluroid fish. ×2.
a. Posterior view of dorsal spine fragment; *b*. Anterior view of same; *c*. Dorsal view of pectoral spine fragment; *d*. Ventral view of same.

A large portion of the articular head of the pectoral spine, K 40/279 *b*, (Pl. 13, figs. 28-29; text-fig. 8, *c* and *d*) is broken off. The shaft is greatly compressed and along the ventral surface of its proximal portion there is a fairly deep fossa and a groove in its continuation. The spine is devoid of any ornamentation.

The identification of these two fragments is only provisional, as the fragments are rather of a generalised nature.

The Siluroids are among the dominant fishes of the present day and date back to the Eocene period.

Super-Order PERCOMORPHI.

Order SCOMBROIDEA.

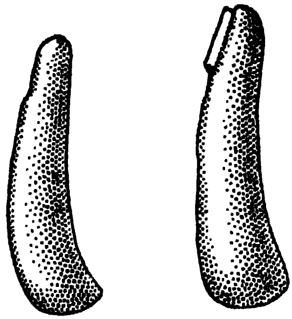
Family *TRICHIURIDAE.*

Genus TRICHIURUS Linnaeus.

(Plate 13, figs. 30-31; text-fig. 9.)

Material.—Specimens Nos. K 40/313 *a*, *b* (two isolated teeth). Collected by Mr. J. G. Gilson at Soro.

The teeth are compressed, smooth and fairly large; they are slightly curved. I have compared these teeth with those of *Trichiurus savala* Cuv. & Val. and found a close agreement between them.



TEXT-FIG. 9.—Fossil teeth of *Trichiurus* Linnaeus. ×4.

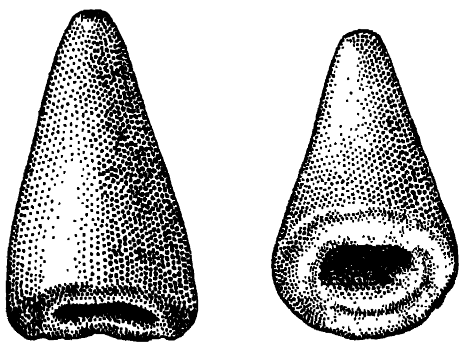
Dr. E. I. White also examined the two specimens and found that they very likely belong to *Trichiurus* " but their state is such that I am quite certain that they are not specifically identifiable ".

The Trichiuridae range from the Eocene to the present times.

Incertae Sedis.

(Plate 13, figs. 32-33; text-fig. 10.)

Material.—Nos. K 40/276 *a, b* (two isolated teeth). Collected by Mr. N. H. Cour-Palais at Balasore.



a *b*

TEXT-FIG. 10.—Apical portion of a fossil Scombrioid tooth. ×5.
a. Side view; *b.* Slightly tilted view to show hollow nature of tooth.

The two isolated teeth, to which I have not been able to assign any definite generic position, probably represent the apical portions

of some type of Scombrioid teeth. The teeth are compressed and of different form and sizes. One large tooth (Pl. 13, fig. 32; text-fig. 10), probably a principal tooth of the dentary or palatine, is fairly broad, symmetrical and bent inwards; it gradually tapers to the apex. The other tooth, probably the lamiary tooth of premaxilla or dentary, is narrower, somewhat asymmetrical and only slightly bent. Both the teeth are ornamented with fine longitudinal ridges and are hollow; the central cavity being fairly wide.

Superficially the fossil teeth appear similar to those of *Sphyraena* Artedi, but the teeth of the present-day species of the genus that I have examined are solid.

Owing to a superficial resemblance of these teeth to those of *Pristis ensidens* Leidy (1877) and *P. cudmorei* Chapman (1917), I got confused regarding their systematic position, so I sent the material to Dr. E. I. White. He found the two teeth described above as belonging to an indeterminable genus of Scombrioid fishes; while another tooth-like structure, K 40/276 *c*, (Plate 13, fig. 34) he considers as the finger from the claw of a crab.

The modern Scombrioid fishes, as a whole, do not date back to an earlier period than the Eocene.

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EXPLANATION OF PLATE.

Fossil Fish-Remains from Balasore.

FIGS. 1-4.—Teeth of *Carchariolamna heroni* gen. *et* sp. nov. ×2.
FIGS. 5-6.—Teeth of *Oxyrhina* Agassiz. ×2.
FIGS. 7-10.—Teeth of *Prionodon* Müller & Henle. ×2.
FIGS. 11-14.—Teeth of *Scoliodon* Müller & Henle. ×2.
FIG. 15.—Tooth of *Hypoprion* Müller & Henle. ×2.
FIGS. 16-20.—Teeth of *Aprionodon* Gill. ×2.
FIGS. 21-24.—Fragments of isolated centre-teeth of *Myliobatus* Cuvier. ×2.
FIG. 25.—A portion of the tail-spine of a Myliobatid fish. ×1½.
FIG. 26.—Posterior view of a dorsal spine fragment of a Siluroid fish, probably *Arius* Cuvier. ×2.
FIG. 27.—Anterior view of above. ×2.
FIG. 28.—Ventral view of a pectoral spine fragment of a Siluroid fish, probably *Arius* Cuvier. ×2.
FIG. 29.—Dorsal view of above. ×2.
FIGS. 30-31.—Teeth of *Trichiurus* Linn. ×2.
FIGS. 32-33.—Apical portions of Scombrioid teeth. ×2.
FIG. 34.—Finger from the claw of a crab. ×2.

NOTE ON ECHINOIDEA FROM BURMA. BY ETHEL D. CURRIE, B.Sc., PH.D., F.G.S. (With Plate 14.)

These echinoidea from Burma which have been entrusted to me for examination by the Director of the Geological Survey of India, were collected by Theobald between the years 1865 and 1868. They fall into two groups. The first group comprises representatives of four species preserved in a cream-coloured gritty limestone which has evidently suffered considerable disturbance for the specimens are all more or less crushed and sheared and many are broken. This material is from the Pegu stage of Gnathamoo on the West Coast of Arakan. Some of the specimens were evidently determined by A. v. Kraft (according to the labels) as far back as 1879 for there is a reference to them in the first edition of Medlicott and Blanford's 'Manual of the Geology of India', Pt. II, p. 721. They are also referred to in Oldham's 2nd Edition (1893, p. 340). My examination of the specimens in this group confirms these early determinations, *viz.*, that the *Echinolampas* is *E. jacquemonti* Duncan & Sladen, a common fossil of the Gaj group (Miocene) in Sind and that the *Amphiope* (*Echinodiscus*) closely resembles a Gaj species. The other two species from Gnathamoo are not reliable indices of age as the specimens are very poorly preserved but their evidence, so far as it goes, is consistent with a Miocene age.

The other group consists of 30 specimens, all iron-stained and more or less weathered, of one species (*Dicoptella promensis* sp. nov.) from the Pegu stage of Eastern Prome and the Pegu River. They were determined by A. v. Kraft (according to the label) as *Pseudodiadema* and are referred to in Medlicott and Blanford (1879, p. 720) and Oldham (1893, p. 340) as belonging to 'a genus of echinoderms with Cretaceous affinities'. This conclusion cannot now be upheld. The species is characterised by well defined sutural pits or fossettes and is here described as *Dicoptella promensis* sp. nov. It is not however a typical *Dicoptella* and is not closely related to any other known species. A definite conclusion regarding age is therefore not possible but comparison with other species suggests Upper Miocene as probable.

Echinoids from Gnathamoo, West Coast of Arakan.

Family *SCUTELLIDAE.*

Genus AMPHIOPE Agassiz, 1841.

Amphiope cf. *placenta* (Duncan & Sladen).

Plate 14, figs. 1-4.

Echinodiscus placenta Duncan & Sladen, 1885, p. 329, pl. LI, fig. 7 & pl. LII, figs. 1-3 & 8.

Material.—Four specimens showing fairly complete apical surfaces together with numerous fragments of tests. The specimens are all crushed and distorted to some extent.

Locality.—Gnathamoo, West Coast of Arakan.

Horizon.—Pegu stage.

Remarks.—These specimens, in spite of their state of preservation and the fact that *A. placenta* Duncan & Sladen is not completely known, are evidently closely similar to that species. The original shape, relative size and general conformation of the petals must have been the same as in *A. placenta.* The shape of the test also was no doubt similar to that of *A. placenta* although two of the specimens from Burma (G. S. I. Nos. K10/186a and K10/186b) appear to be less contracted in ambital outline towards the anterior than is the specimen of *A. placenta* figured by Duncan & Sladen, pl. LII, fig. 1.

A more definite point of disagreement with *A. placenta* as figured by Duncan & Sladen can be seen in the shape of the lunules. Allowing for the broken and distorted state of the lunules in the specimens from Burma, one can only conclude that they are more elongated radially than those of the figured specimen of *A. placenta* and that they extend nearer to the margin of the test and to the extremities of the petals. The only complete lunule which is also the least distorted (in G. S. I. No. K10/186c) is figured Pl. 14, fig. 3 (nat. size). It is about 15 mm. long and 5½ mm. wide; it is about 6 mm. from the end of the petal (about 23 mm. in length) and it is at least 5 mm. from the margin of the test. As shown by Lambert (1912, p. 75),

Cottreau (1913, p. 136) and Albaille (1935, p. 66), the shape of the test and of the lunules in *Amphiope* vary considerably within a species; hence the points mentioned above are not necessarily arguments against assigning the specimens from Burma to *A. placenta*. It seems reasonable to assume, until contradictory evidence is available that *A. placenta* is variable to some extent and that the specimens from Burma probably represent a type of variation within the species.

Amphiope desori (Duncan & Sladen) from the Miocene of Kachh (D. & S., 1883, p. 60, pl. XII, figs. 7-10) and Sind (D. & S., 1885, p. 328, pl. LI, figs. 1-3) seems to have lunules of proportions similar to those of the *Amphiope* under discussion but in *A. desori*, the rosette is smaller in relation to the size of the test and the details of the petals are different.

The underside of *A. placenta* D. & S. is not known. Some idea of the appearance of the undersurface of the Burman *Amphiope* can be obtained from examination of fragments of tests which show traces of the ambulacral furrows. The furrows bifurcate near the mouth and extend towards the margin, those of ambulacra I & V being gently curved past the lunules while the others (in II, III & IV) are almost straight. The course of an ambulacral furrow near the margin of the test can be seen clearly in only one fragment (G. S. I. No. K10/186d) figured Pl. 14, fig. 4. This furrow does not extend to, or fade out at the margin. It is fairly uniform in width and at a point some distance from the margin (about 12 mm.) it curves through a right angle and is continued as a thin lateral branch. This branch is comparatively long, its course is approximately parallel to the margin of the test and it ends with a downward curve. A less distinct and smaller lateral branch, roughly parallel to the one just described leaves the furrow at a point twice the distance of the first branch from the margin. Traces of other very short and very faint branches can also be made out. The configuration of the ambulacral furrows of the Burman *Amphiope* was probably not unlike that of *Amphiope arcuata* Fuchs (Fuchs, 1882, p. 49, pl. XVI, fig. 5 and pl. XV, fig. 2 and Fourtau, 1920, pl. IV, fig. 2) from the Egyptian Miocene except that in *A. arcuata* there is only one lateral branch and that the furrow is continued towards the margin beyond the junction of the branch. Relative size and details of the petals also distinguish the Burman *Amphiope* from *A. arcuata*.

Family *CASSIDULIDAE.*

ECHINALAMPAS Gray, 1825.

Echinolampas jacquemonti d'Archiac & Haime.

Plate 14, fig. 5.

Echinolampas jacquemonti d'Archiac & Haime, 1853, p. 211, pl. XIV, fig. 5a, b.
Echinolampas jacquemonti Duncan & Sladen, 1885, p. 332, pl. LIII, figs. 1-14.

Material.—59 specimens all more or less distorted. Some are broken. The specimen figured is only slightly sheared.

Locality.—Gnathamoo, West Coast of Arakan.

Horizon.—Pegu stage.

Remarks.—Duncan & Sladen (*loc. cit.*) drew attention to the variations in form they found in specimens of this species from the Gaj Series of Sind. Well preserved and abundant specimens of *E. jacquemonti* forming an extremely variable series, have also been described from the middle Fars series (Mio-Pliocene) of Persia by J. A. Douglas (1928, p. 12, pl. VIII, fig. 2) who noted that the various forms of *E. jacquemonti* figured by Duncan & Sladen can be matched among the Persian examples of the species. Clegg (1933, p. 26) has recorded a series of 7 varying forms of *E. jacquemonti* from the Lower Fars (Helvetian) of S. Persia.

The examples of *E. jacquemonti* from Burma appear to be mainly of one type—that of the specimen (G. S. I. No. K 10/186e) figured Pl. 14, fig. 5. This form with elongate test, rostrate posterior, high aboral surface with subconical elevation at the apex, is obviously the same as the form figured by Duncan & Sladen, *loc. cit.* pl. LIII, figs. 3-5 and might be called their elongate, subconical' type. Two specimens (G. S. I. No. K 10/186f) suggest that the 'sub-depressed' form described by Duncan & Sladen (*loc. cit.* figs. 1 & 2) is also represented among the 59 specimens from Burma; and two other specimens (G. S. I. No. K 10/186g) show some resemblance to their 'subrotund' form (*loc. cit.* figs. 8-10). While more than half the specimens from Burma are too crushed and deformed to give indications of their original shape, those which do retain something of their natural form are, with the few exceptions just mentioned, of the 'elongate subconical' variety. At least 24 specimens represent this form.

Family *BRISSIDAE.*

Schizaster Agassiz, 1836.

PARASTER Pomel, 1869.

Schizaster (Paraster) granti Duncan & Sladen.

Schizaster granti Duncan & Sladen, 1883, p. 70, pl. VI, figs. 8-12 and p. 88.
Schizaster granti Duncan & Sladen, 1884, p. 268, pl. XLII, figs. 4-6.
Schizaster granti Duncan & Sladen, 1885, p. 339.

Material.—Three poorly preserved specimens G. S. I. No. K10/186h).
Locality.—Gnathamoo, West Coast of Arakan.
Horizon.—Pegu stage.
Remarks.—These specimens are referred to *S. granti* from the Nari and Gaj Series of Sind and the Miocene of Kachh and Kattywar, because of their strong general resemblance to that species. Unfortunately, their state of preservation prevent comparison of details of fascioles and peristome but at least no definite point of difference from *S. granti* can be seen.

Lambert & Thiéry (1925, p. 526) retain this species in *schizaster* whereas others would no doubt refer it to *Paraster* on account of its 4 genital pores. For convenience, both names are given here as genus and sub-genus.

Family *SPATANGIDAE.*

BREYNIA Desor, 1847.

Breynia cf. *carinata* (d'Archiac).

Breynia carinata d'Archiac & Haime, 1853, p. 216, pl. XV, fig. 4.
Breynia carinata Duncan & Sladen, 1883, p. 66, pl. X, figs. 1-4.
Breynia carinata Duncan & Sladen, 1885, p. 343, pl. 54, figs. 1-8 and pl. 55, figs. 1-8.

Material.—A small fragment of a test (G. S. I. No. K 10/187a).
Locality.—Gnathamoo, West Coast of Arakan.
Horizon.—Pegu stage.
Remarks.—One must point out that the reference of this fragment to *Breynia carinata* is merely a tentative suggestion for the specimen is too incomplete for accurate identification. According

to Duncan & Sladen (1885, p. 343) *Breynia carinata* abounds in the Gaj beds of Sind and is the most characteristic species of the Miocene of that area. *B. carinata* is, moreover, the only species described by d'Archiac & Haime and Duncan & Sladen from India to which such a fragment could belong. For these reasons, the comparison is made for what it is worth.

Echinoids from Eastern Prome and Pegu River.

Family *TEMNOPLEURIDAE.*

Genus DICOPTELLA Lambert, 1907.

Dicoptella promensis sp. nov.

Plate 14, fig. 6; text-figs. 1—5.

Diagnosis.—A *Dicoptella* with high interambulacral plates and an appearance of overlap in those situated adapically. Main tubercles large. Fossettes triangular, broadly so to pear-shaped or loop-shaped adapically, becoming gradually narrower towards the ambitus where they are shaped like thin wedges. Fossettes absent below the ambitus.

Material.- Holotype (G. S. I. Type No. 16744) and five paratypes (G. S. I. Type Nos. 16745--16749) together with about 24 other specimens. The test are all more or less weathered and iron-stained. The holotype, in which the apical disc is missing, has suffered little abrasion of the surface of the coronna. The other specimens present a great variety of stages in weathering.

Locality.—Eastern Prome and Pegu River.

Horizon.—Pegu stage.

Dimensions.—Tests vary from 32·9 mm. to 17·3 mm. in diameter. Height is from ·46 to ·52 of the diameter.

Holotype.—Diameter 22·3 mm., height 11·7 mm., diameter of peristome 4·5 mm.

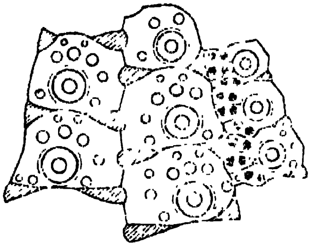
Description of holotype.—Test circular in ambital outline. Upper surface rounded, depressed, height about half the diameter. Lower surface rounded at the margin and forming a deep depression for the peristome.

Ambulacra about $\frac{3}{4}$ of the breadth of the interambulacra at the ambitus; depressed adapically where the interambulacra project

above the level of the pore-fields. Pore-pairs with interporal granule, in arcs of three on each compound plate which is probably composed of two primary and an intermediate demi-plate (fig. 4). Pairs of pores situated in deep depressions and hence have the appearance of being separated from one another by prominent ridges. Each plate of which there are about 20, bears a primary tubercle (imperforate and non-crenulate) situated centrally with regard to the transverse sutures and adjacent to the pore-fields. In a few plates just above the ambitus, a secondary tubercle occurs on the perradial side of the main tubercle. Tubercles occur in the pore-fields. A quite large one is situated between the middle pore-pair (on each compound plate) and the main tubercle. A smaller one occurs between the adapical pore-pair and the main tubercle and one (or two) separate the adoral pore-pair from the adradial suture. Above the ambitus, there are sutural fossettes, roughly triangular in shape with their wide ends at the perradial suture.

Interambulacral plates, about 16 in a column, high adapically, becoming gradually lower and wider towards the ambitus and from there becoming again narrower adorally. Median suture depressed. In 6 or 7 adapical plates, the adapical transverse edge projects above the level of the adjacent plate and thus produces an appearance of overlap towards the apex. It is not a real overlap as the sutures of the plates are definitely at right angles to the surface of the test. Main tubercles (imperforate and non-crenulate) situated slightly adradially to the centres of the plates and close to the adoral sutures. Bosses of tubercles surrounded by narrow depressed scrobicules. Scrobicular circles almost contiguous with the adoral sutures of the plates although the apparent overlap of the plates makes them appear confluent from certain points of view. Except in the first 5 adapical plates, a secondary tubercle occurs in the interradial angle of each plate. At the ambitus, these secondaries are almost as large as the primaries and from there they decrease in size adapically and adorally. Tertiary tubercles occur singly or in pairs set vertically, on each plate on the adradial side of the main tubercle adjacent to the pore-fields. In addition, small tubercles of varying sizes occur on the plates forming irregular scrobicular rings. Often three or two of these tubercles, larger than the others, occur in a line above the main tubercle. Fossettes occur above the ambitus and are absent below that line. Adapically they are large, those at the interradial suture loop-shaped or

pear-shapped while those situated adradially are roughly train-gular. Both have their pointed ends directed towards the main



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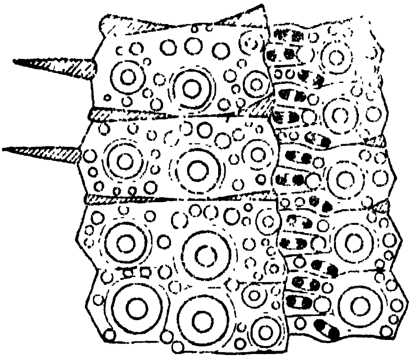

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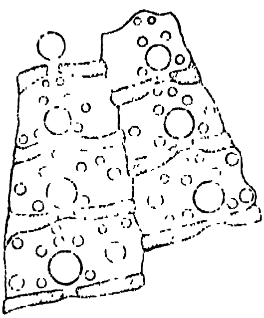

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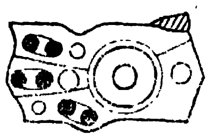

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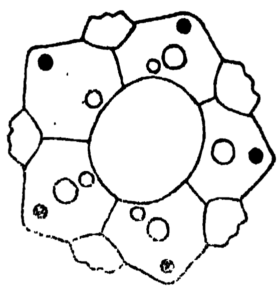

(5)

FIGS. 1--5. *Dicoptella promensis* sp. nov. Diagrammatic drawings All greatly enlarged.

(1) Part of the holotype (G. S. I. Type No. 16744) to show the ambulacra and interambulacra in the adapical region. (2) Part of the same specimen at the ambitus. (3) Part of an interambulacrum of paratype G. S. I. Type No. 16746 to show the effect of weathering. (4) An ambulacral plate (from G. S. I. Paratype No. 16745) to show its composition (two primaries and a median demiplate). (5) Reconstruction of the apical system based on paratypes G. S. I. Type Nos. 16746—16749.

tubercle. The fossettes become gradually longer and more compressed towards the ambitus where they are shaped like long thin wedges.

Peristome small, about 1/5 of the diameter. Branchial incisions narrow.

Paratypes.—The structure of the apical system can be made out though not perfectly clearly, from the apical discs of the five paratypes. These specimens being badly weathered, are less well preserved than the holotype. The disc is pentagonal with large excentric periproct and its surface is arched and projecting. The periproct appears to be slightly elongated in the direction of amb. I -interamb. 4. The two anterior genitals are larger than the others and all have a perforation near the angular margin. Madreporic pores cover the greater part of the right anterior genital plate. Trace of large tubercles can be seen round the periproct and there was probably an inner circle of smaller tubercles adjacent to the periproct. Oculars small and all exsert.

Two of the paratypes (G. S. I. Type Nos. 16746 and 16749) show a tendency towards a slightly pentagonal ambital outline.

Weathering.—The effects of weathering are so varied as to deserve special note. The first and main effect of weathering is to enlarge the sutural fossettes in such a way that a weathered specimen could easily be mistaken for an entirely different species. The fossettes, originally roughly triangular, tend to become more or less rectangular and in the interambulacral areas, to extend along the length of a suture line except for a narrow band below the main tubercle. In this state, the fossettes resemble those of the recent (and fossil) *Dicoptella agassizi* Lambert & Thiéry and *Dicoptella maculata* Mortensen more closely than those of an unweathered *D. promensis*. In an even more advanced stage of weathering, where all the surface features of the test are almost worn away, the fossettes also tend to disappear showing that they are not deep pits and do not undermine the test even in weathered specimens.

Remarks.—The most recent revision of the genera of the Temnopleuridae which have sutural fossettes, sometimes known as 'Sculptés', is that by J. Lambert in Lambert & Jeannet, 1935, pp. 3-8. According to the limits of the genera set out in this paper, the present species is evidently closely related to *Dicoptella* Lambert and *Temnechinus* Forbes. The main difference between *Dicoptella* and *Temnechinus* appears to be the presence in *Temnechinus* of grooves in the adapical parts of the interambulacral areas formed by the confluence of the median fossettes. The late J. W. Gregory (1892, pp. 29-32) believed these grooves to be brood pouches and suggested

that investigation of similar grooves in recent specimens of *Tripneustes variegatus* would help to prove his views regarding sexual dimorphism in the Crag Temnechini. So far as I can find, no such investigation has ever been carried out; but whatever the nature of the interambulacral grooves in *Temnechinus*, it is no doubt advisable to separate species in which they occur (*Temnechinus*) from species in which they appear to be absent (*Dicoptella*).

Only one specimen out of 30 of the present species shows any suggestion of confluence of the adapical interambulacral fossettes and careful examination proves this to be merely an appearance of confluence produced by weathering. This being so, these specimens are referred to *Dicoptella* Lambert (=*Pleurechinus* (in part) of Mortensen, 1904, p. 91 and =*Temnotrema* (in part) of Clerk, 1912, p. 317 and 1925, p. 189 and Koehler, 1927, p. 93).

Lambert's genus *Dicoptella* (1907, p. 7 and 20 and Lambert & Thiéry, 1910, p. 232) has not been recognised by H. L. Clerk and R. Koehler according to whose ideas this species would probably be named *Temnotrema*. Clerk (1912 & 1925) in dealing with *Temnotrema* has omitted any reference to Dicoptella; Koehler (1927) has regarded *Dicoptella* as a synonym of *Temnotrema*. According to Lambert (1935, *loc. cit.*) *Dicoptella* is distinct from *Temnotrema* which is classified with *Temnopleurus* in a group with crenulate tubercles. Not having seen the holotypes of the critical species I am not in a position to offer an opinion of any value on this matter and am following Lambert in adopting *Dicoptella*, because his paper of 1935 is the most recent summary of the 'Sculptés' generally. His claim that *Dicoptella* is distinct from *Temnotrema* depends mainly on his conclusion that *Temnotrema sculpta*, the geno-holotype of *Temnotrema*, is the young of *T. hardwickii*. If this is the case, which one virtually accepts in adopting *Dicoptella*, the young and adult stages must both go under one name, the older name, *Toreumatica hardwickii* Gray (1855, p. 39). *Temnotrema* Agassiz (1863, p. 358) thus becomes obsolete.

Comparison with other species shows that *D. promensis* is not a typical *Dicoptella* differing as it does, from other species, in the comparatively great height of the interambulacral plates and the large size of its main tubercles. This is particularly noticeable in the adapical interambulacral plates which are farther characterised by an appearance of imbrication.

The only species which invites comparison with *D. promensis* is *D. tobleri* Jeannet (in Jeannet & Lambert, 1935, p. 39, pl. II, figs. 10-15 and pl. IV, figs. 6 and 14) from the Upper Miocene of Java but the resemblance is mainly in the shape of the fossettes and the two species are easily distinguishable. *D. promensis* has a flatter test than *D. tobleri* although the plates are higher; and its tubercles are larger, than those of *D. tobleri.* There also appears to be a greater development of secondary and tertiary tubercles in *D. promensis.* The fossettes in the region just above the ambitus are similar in the two species but while the adapical fossettes of *D. tobleri* are rounded those of *D. promensis* are larger, pear-shaped or loop-shaped interradially and roughly triangular adradially. Then again, fossettes are absent below the ambitus in *D. promensis.*

In conclusion, I wish to think Professor A. E. Trueman for reading the MS of this note and for helpful suggestions.

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LIST OF ILLUSTRATIONS.

FIGS. 1-4. *Amphiope* cf. *placenta* (Duncan & Sladen).

FIG. 1. Apical surface of a large specimen (G. S. I. No. K 10/186a) ½ Nat. size.

FIG. 2. Apical surface of another specimen (G. S. I. No. K 10/186b) in which the petals are fairly well preserved ½ Nat. size.

FIG. 3. Part of apical surface of another specimen (G. S. I. No. K 10/186c) to show proportions of the lunule Nat. size.

FIG. 4. Adoral view of a fragment of a test (G. S. I. No. K 10/186d) to show the course of an ambulacral furrow near the margin. Nat. size.

FIG. 5. *Echinolampas jacquemonti* d'Archiac & Haime. G. S. I. No. K 10/186e Nat. size.

FIG. 5a. Apical view.

FIG. 5b. Side view.

FIG. 6. *Dicoptella promensis* sp. nov. Holotype (G. S. I. type No. 16744) × 2.

FIG. 6a. Apical view.

FIG. 6b. Oral view.

FIG. 6c. Side view.

THE UNDERGROUND WATER-SUPPLY OF THE PESHAWAR AND MARDAN DISTRICTS OF THE NORTH-WEST FRONTIER PROVINCE; WITH AN APPENDIX ON THE KOHAT VALLEY.

BY A. L. COULSON, D.Sc., D.I.C., F.G.S., F.N.I.,
Superintending Geologist, Geological Survey of India.

CONTENTS.

I. INTRODUCTION.

I recently completed a study of the sub-soil water supply of the Mianwali and Isa Khel *tahsils* of the Mianwali district of the Punjab, the report being published by the Government of that Province by the Government Printing Office, Lahore, (1938). Additional data were incorporated and the report was published in the *Records* of the Geological Survey of India.[1] In consequence of my geological work in the Peshawar and Mardan districts of the North-West Frontier Province during the past three years, I have become very interested in their water-supply. An enquiry by the Electricity Department of the Government of the Frontier Province with regard to tube-wells near the Grid Sub-Stations at Nowshera, Mardan and Charsadda, and questions by the Deputy Commissioner, Mardan district, regarding subterranean water in certain areas of his district, have stimulated my collection of the available data,

[1] *Rec. Geol. Surv. Ind.*, 72, Pt. 4, pp. 440-466, (1938).

and it would seem useful to place this information on record in easily accessible form, for the benefit of those concerned with water-supply problems in the Peshawar and Mardan districts. A smaller report on the tube-wells mentioned above has already been submitted to the Local Government. This present, larger, report contains much of the information upon which my conclusions in the smaller report were based. Its data have been derived from a variety of sources and I offer my sincere thanks to the numerous Civil and Military officers who have assisted me.

I may mention here that I make no apology for dealing at somewhat great length with the water-supply of the Mardan area. The question of a water-supply scheme there is extremely urgent and it may be that the information and suggestions in this report will be of some assistance to those concerned in this matter.

II. GENERAL DISCUSSION.

Ancient lake in Vale of Peshawar.

When one crosses the Indus into the Frontier Province by the Attock Bridge (33° 52′ : 72° 14′), that gateway to the Vale of Peshawar, one is struck by the fact that the whole of the drainage of the Peshawar and Mardan districts is regulated by the level of the basement Attock slates over which the Indus flows. In a previous paper on "Pleistocene Glaciation in North-West India, with special reference to the Erratics of the Punjab"[1], I have drawn attention to the changed position of the Indus from the days when it was a tributary of the Indobrahm, that postulated mid-Tertiary river flowing into the Bay of Bengal along the course of which, probably in two or more paleo-geographical basins, the extensive Siwalik deposits were laid down. I also noted that the final earth movements that resulted in the dismemberment of the Indobrahm prevented the Indus from flowing round the Kala Chitta hills and forced it to find a new outlet for its waters and sediments. This it eventually did by cutting through the Attock hills; but meanwhile it was dammed above the gorge and a considerable amount of lacustrine deposits were laid down in the resultant lake that occupied a greater or lesser part of the Vale of Peshawar. I do not wish at this point to discuss the climatic conditions pertaining at the time of the existence of that lake, whether or not it coincided with

[1] *Rec. Geol. Surv. Ind.*, 72, Pt. 4, pp. 422-439, (1938).

one of the Pleistocene glacial phases. However, quite a considerable quantity of detritus was laid down by the outwash fans of streams debouching into it and in its placid waters. The evidence of tube-wells sunk in the vicinity of Peshawar, Risalpur and Mardan shows, in fact, that the solid basement rocks of the Peshawar and Mardan districts were not met with by borings sunk in the alluvial and lacustrine deposits to depths considerably below and nearly at the level of the bed of the Indus river at the Attock gorge. The superincumbent weight of detritus and sediment poured on to the Vale of Peshawar, using this term in its general sense as including the whole valley of the Kabul river within the Frontier Province proper, may have been sufficient to depress the bottom of the Vale. Alternatively, down-warping may have permitted the accumulation of sediments. The sinking was no doubt gradual and more or less corresponded with the deposition of material. The interconnection of this unstable floor with local earthquakes need not be discussed here.[1] One may note, however, that this lake we have described was possibly not of long duration; but after its water had gained free exit by means of the Attock gorge, the drainage of the Vale of Peshawar was a gradual process and no doubt marshy conditions persisted for some time. We are reminded of the fact that when Alexander and his armies entered India in 327 B. C., he is supposed to have negotiated the Vale of Peshawar around its northern margin, abutting against the hills here, presumably on account of the treacherous nature of the swampy marshy ground flooring it.

Recent rise of water-level.

With the introduction of intensive irrigation from the Swat canals, we have had within recent years an enormous quantity of water poured on to the surface of the ground, not all of which has been able to escape. Certain streams, formerly dry for much of the year, now show water perennially. One need but quote the example of the Kalpani river, that important tributary of the Kabul river which joins it just below Nowshera. Not so very long ago, before the days of irrigation, the Kalpani, although never dry for the last sixty years, contained but little water for most months in the year. The present minimum discharge of that river throughout the year is more than 200 cusecs.

[1] The lacustrine deposits near Nandrak (34° 1′ : 72° 11′), which are very similar to the Karewas, show dips as high as 29°; nearby they are domed. Considerable recent movement has thus affected them.

This enormous amount of irrigation water added to the surface must be largely responsible for the deterioration bacteriologically of the upper sub-surface water.

Drainage level at Attock gorge.

We may now reconsider the barrier of Attock slates that blocks the drainage of the Indus and its tributary the Kabul river above the Attock gorge. According to the one-inch topographical sheet 43 C/1, one of the small gravel islands, or *belas*, in the Indus river just north of Attock, which island is of course covered by summer flood-water when the snows of the Himalayas are melting, is shown as having a bench mark 917 feet above sea-level. The Attock Bridge is shown as 1,007 feet above sea-level. I have assumed that the minimum depth below which the Indus water will not be able to percolate freely through the barrier of Attock slates is approximately 800 feet above sea-level. This is some 117 feet below the island referred to above and 207 feet below the Attock Bridge and I think that it forms a reasonably fair limiting level for the general sub-surface drainage of the Indus river and its tributary the Kabul river above the Attock Bridge. Certainly there may be fissures which will allow water below this level of 800 feet to escape; but their effect will be negligible when considered in the light of the major question of the drainage of the whole valley.

We should bear in mind this figure of 800 feet above sea-level when we consider water-supply questions in the valley of the Kabul river and its tributaries in the Peshawar and Mardan districts. Naturally as one goes upstream from the Attock area, any limiting drainage level will increase. However, there are so many interacting factors at work that it is idle even to attempt to give limiting levels for various places such as Nowshera (34° 0′ : 72° 0′), Mardan (34° 12′ : 72° 2′) and Peshawar (34° 0′ : 71° 33′). To mention but one point, water may be met with when boring below this limiting depth, which may be under sufficient hydrostatic head to bring it to the surface, far above the limiting drainage level.

Actual effect of limited drainage as yet uncertain.

The actual effect of this limiting drainage level at the Attock gorge as yet cannot be ascertained. No chemical analyses of water from above and below this depth are available. In the case of the Mianwali district of the Punjab, with a free drainage, one noted a gradual improvement in the quality of the sub-soil water with depth. In the Peshawar and Mardan districts, with their limited

drainage, there may be more equalisation in the quality of water with depth. The point to be borne in mind is that water occurring below this limiting level of 800 feet above sea-level will normally be *stagnant* water, meaning that it does not usually seep away. One would expect it to be harder than the water immediately above this limiting level. It would seem to follow that the best water to utilise in the Peshawar and Mardan districts is the intermediate underground water, obtained at a depth sufficient to warrant it being uncontaminated with dissolved salts and bacteria from surface irrigation water, and not sufficiently deep to come from below the limiting drainage level.

However, as irrigation proceeds, there will be less and less difference in the quality of the underground water.

Conditions dissimilar to those above a weir.

It has been suggested to me that the conditions pertaining in the Vale of Peshawar above the barrier at the Attock gorge are exactly similar to those above a weir; but with this suggestion I cannot agree. The water impounded above a weir is continually changed owing to the action of convection currents and to many other causes. Though a certain amount of the water below the limiting drainage level in the Vale of Peshawar will be changed, the flow of such water will in general be slow, owing to the tortuous course along which it has to percolate before reaching the exit. Such water below drainage level cannot, I consider, under any circumstances be likened to the free conditions above a weir, where the water has no relatively impermeable medium through which it must percolate and which acts as a barrier to the formation of convection currents on any appreciable scale. The conditions, in fact, are very like those in an over-irrigated area, where the lower water is to all intents and purposes stagnant. As I have stated previously, the exact effect of the barrier is as yet uncertain, as we have not obtained sufficient information regarding the chemical characteristics of the water below the limiting drainage level. However, it would seem most likely that the barrier to the drainage at the Attock gorge will tend to cause equalisation in quality of the underground water, especially if intensive irrigation is allowed to continue.

The question of bacteriological contamination of water in depth is a matter of considerable difference of opinion. I have referred

to the limiting drainage level of 800 feet above sea-level. This level is generally more than 200 feet below ground-level in the Peshawar and Mardan districts. I personally find it difficult to believe that water which occurs at a depth of 200 feet or more below ground level will be contaminated bacteriologically, as *e.g.*, was stated to be the case for the tube-well sunk at Mardan in the Divisional Officer's compound. Such water generally has passed longitudinally through many miles of natural filter-beds, as it is ordinarily impossible for surface water to percolate vertically down through the usual succession of impervious clay beds that alternate with porous sandy beds in most parts of the Vale of Peshawar. On the one hand, I have seen it stated that in Lahore and Ferozepur, when it was found that water was contaminated to a depth of 200 to 250 feet, all water from the surface was sealed off and water from 300 feet was proved to be bacteriologically pure. On the other hand, with regard to Lahore, it has been authoritatively stated by Mr. D. A. Howell, Superintending Engineer, Public Health Circle, Punjab (D. O. to Deputy Commissioner, Mardan, dated 10th August, 1938) that

Bacteriological infection.

"It is not uncommon for samples of water extracted from alluvial trial borings to be found contaminated, although actually the water in the ground itself is quite pure. The reason is that the borehole pipes themselves, the ropes, sludgers, etc., and the men handling these appliances, are probably contaminated. Such contamination of course disappears after the tube-wells are pumped for a little while. At Lahore where we have put down numerous tube-wells extending from about 150 to 500 feet depth, I know of no case of contamination of the water supply taken from completed strainer tube-wells even only 100 feet below the subsoil water level nor do I know of such case in any other place where the tube-wells are in the alluvium."

It is interesting to note that in the Lee valley, forming portion of the area for the water-supply of London under the control of the Metropolitan Water Board[1], there are two distinct classes of deep wells—those protected by beds of clay above the chalk and those not so protected. The former class are of high bacteriological grade; and if at any time they fall below standard, they are chlorinated before delivery of water from them to consumers. The latter class are not used as direct sources, but water from them is pumped

[1] "The Water Supply of London. Report for 1937," *British Medical Journal*, p. 567 (March 18, 1939) [abstract of "Thirty-second Annual Report on the Results of the Chemical and Bacteriological Examination of the London Waters for the Twlcve Months ended December 31, 1937," by C. H. H. Harold, London, (1939)].

into the New River to undergo purification along with the river water.

To conclude this general discussion, I stress the need for great care in the collection of samples of water for examination, whether bacteriologically or for their mineral salt contents, from intermediate and final depths in tube-wells. This is necessary to prevent contamination by surface or upper sub-soil water. It is interesting to wonder how many tube-wells have either been abandoned or taken to greater depths than was necessary on account of poor sampling of water from their intermediate and final depths.

Need for great care in sampling water.

III. PESHAWAR AREA.

Peshawar gets its water-supply from the Bara river. There have been, however, three deep tube-well bores sunk in the Cantonment area and a fourth at the Islamia College (34° 0′ : 71° 28′), a few miles from the Cantonment on the Khyber road. When my colleague, Mr. W. D. West, visited Peshawar in 1934 in connection with various water-supply questions in the Peshawar district, he had available only the results of the Islamia College boring (295 feet deep) and that in the Locomotive Sheds (207 feet deep) near the Cantonment railway station.

W. D. West.

With regard to the Islamia College boring Mr. West stated :—

Islamia College.

"The ground level here is approximately 1,190 feet. The details of the boring show that for the first 105 feet the rock is mainly gravel. But from 105 to 117 feet there occurs a stiff clay from below which a good supply of water was obtained. From 117 feet to the end of the boring various sands and gravels, all water bearing, were encountered. On testing the supply of water by pumping, there was obtained an output of 8,450 gallons an hour, with a drop in the water level during pumping of two feet. The static water level was 103 feet, that is two feet above the top the clay. It was the opinion of those who put down the boring that the very small drop in level during the test indicated the well was capable of a very much higher delivery, limited only by the size of the eduction pipe fitted. It was considered that with a six-inch eduction pipe up to 20,000 gallons per hour could be delivered."

In January, 1938, in company with Colonel E. W. C. Noel, then Director of Agriculture in the North-West Frontier Province, I visited the site of the Islamia College boring, as there was mooted the possibility of sinking a ten-inch boring to obtain a larger supply of water that could be utilised also for irrigation purposes. We

agreed that the best site would be near the Jamrud road in the south-west corner of the College compound.

Locomotive Sheds.

With regard to the Locomotive Sheds boring near the Cantonment railway station, Mr. West noted :—

"The ground level is here approximately 1,120 feet, and the boring was put down to 207 feet. The details of the boring show that a bed of hard clay was encountered at 68 to 106 feet. After penetrating this bed a good supply of water was obtained, the static level of which was 49½ feet, that is 18½ feet above the top of the bed of clay.

Consideration of these two borings suggests that a prominent bed of clay occurs in the alluvium underlying the cantonment and its immediate neighbourhood. After making allowances for the difference in height between the ground level of the two borings, it is seen that the level of the top of the bed of clay beneath Islamia College is 1,085 feet, while below the railway station it is 1,052 feet. Moreover the bed beneath Islamia College is thinner than that beneath the railway station. Both these observations are in accordance with expectations. Islamia College is nearer the hills than Peshawar itself, and hence the alluvium beneath it is likely to be coarser than that further away from the hills. A stratum with so fine a grain as clay, therefore, is likely to become thinner in this direction, and eventually to die out. In this direction it would also tend to rise slowly. In support of these views *is* the evidence provided by the borings put down at Fort Millward and Fort Salop, which passed through nothing but sand and gravel, since they are close to the foot of the hills. Although the evidence is not very complete, it is probable that the beds of clay overlying the water-bearing strata and sealing in the water at Islamia College and the railway station are part of one and the same stratum of clay which is therefore likely to be found elsewhere within and around Peshawar cantonment.

This bed of clay is of importance in two respects : (1) it seals in the underground supply of water, making it slightly artesian in character ; (2) it also shuts off all surface water, which is likely to be less pure and, as judged from an analysis of the water obtained from a 34-foot well put down by the Peshawar Electric Supply Co., is apt to be slightly bitter in taste and unfit for boiler purposes, due no doubt to the fact that saline efflorescences are generally concentrated in the few feet of the ground nearest the surface."

Roberts' Lines borings.

From the 30th January, 1935, to the 26th April, 1935, an 18- and 14-inch boring (No. 1) was sunk in Roberts' Lines in the Cantonment area to a depth of 500 feet. As the ground-level at the boring is approximately 1,188 feet, this would mean that the bottom of No. 1 boring reached 688 feet above sea-level. Water-bearing strata were met from 129 to 150 feet and from 341 to 360 feet. The upper of these, 129 feet, was thus at a level of 1,059 feet and is very comparable with that tapped at the Locomotive Sheds and Islamia College. The deeper water-bearing stratum at reduced level 837

feet was not reached in either of the two older borings. On the 26th April, 1935, the water level was 65 feet below the surface, *i.e.*, 1,123 feet above sea-level, much higher than the water level in the older borings. This No. 1 boring was subsequently abandoned on account of caving following the pumping of clayey matter after the Hindu Kush earthquake of the 14th November, 1937.[1]

No. 2 boring in the same lines was sunk from the 14th November, 1936, to the 26th January, 1937. The ground-level here was 1,173 feet approximately and water-bearing strata were recorded at depths of 107, 121, 127, 141½, 325, 373 and 380 feet. This boring is 22-inch to a depth of 126 feet and then 16-inch to 415 feet. The reduced level of the base is 758 feet. One or more of the upper water-bearing strata corresponds with the upper one met at 129 feet in No. 1 boring. The main supply is from the 380 feet stratum, *i.e.*, 793 feet above sea-level. This deeper water is said to be distinctly harder than water from the upper water-bearing stratum.

The charts of both borings in the Roberts' Lines show a succession of sand, gravel, shingle and clay beds, but the records were not sufficiently detailed for correlation with the Islamia College and Locomotive Sheds borings.

Summarised statement of bores in or near Peshawar.

The following table summarises the foregoing details of borings made in or near Peshawar :—

TABLE 1.—*Details of borings in or near Peshawar.*

Location.	Islamia College.	Locomotive Sheds.	Roberts' Lines.	
			No. 1.	No. 2.
Depth of boring in feet	295	207	500	415
Size of bore in inches	8	?	18/14	22/16
Reduced ground level in feet	1,190	1,120	1,188	1,173
Level at which water was met in feet.	1,073	1,014	1,059 837	1,066 1,052 1,046 1,031½ 848 800 793
Reduced level to which water rose in feet.	1,087	1,070½	1,123	?
Reduced level of base of boring in feet.	895	913	688	758

[1] A. L. Coulson, *Rec. Geol. Surv. Ind.*, 73, Pt. 1, pp. 135-144, (1938).

It may be noted in conclusion that both borings in the Roberts' Lines go well below the level of 800 feet which I have taken as the limiting drainage level at the Attock gorge. The sole noticeable effect appears to be increased hardness in the water from the lowest water-bearing stratum in No. 2 boring. It will also be concluded that water-supply in the Peshawar area offers little difficulty at the moment.

Conclusion.

IV. KAJURI PLAIN.

It is interesting to note that two deep borings were made at the foot of the hills bordering the Kajuri Plain to the west and south of Bara Fort (35° 55′ : 71° 27′). That at Fort Millward attained a depth of 600 feet, whilst that at Fort Salop was 500 feet deep. Neither of these two borings reached the basement rocks, although both are situated near the hills. Both passed through coarse boulder gravels. As one approaches Peshawar from these borings, one would of course meet gradually less coarse gravels if a boring were made; and eventually, nearer Peshawar, clay bands will begin to appear.

Borings at Fort Millward and Fort Salop.

The general level of the Kajuri Plain south-west of Bara Fort is over 1,500 feet above sea-level, and away from water-courses it might be necessary to go down to a very considerable depth before water-bearing strata are met. Any case of water-supply on the Plain would have to be considered in the light of its own peculiar circumstances.

V. CHARSADDA AREA.

The Charsadda area is drained by the Abazai (Swat) river and its tributaries and it is extensively irrigated. So far no borings have been put down in this region; but one can more or less foretell the nature of the strata that will be met with. One would expect to find predominant sandy and gravelly beds in the upper part and then clays will become more and more important. The sub-surface water level at Charsadda itself (34° 9′ : 71° 44′) is less than 20 feet below ground-level and is approximately 966 feet above sea-level, varying of course to a certain extent with the season.

Sub-soil water level high.

The following table (Table 2) shows the reduced spring level in various surface wells in the Charsadda tahsil:—

TABLE 2.—*Reduced spring levels of surface wells at various villages in the Charsadda tahsil of the Peshawar district during 1937 and 1938.*

Well.	Reduced spring levels in feet.	
	1937.	1938.
Mosque at Abazai village (34° 19′ : 71° 36′)	1,110·21	1,110·51
Gandera village mosque (34° 22′ : 71° 42′)	1,133·05	1,133·1
Ziam Canal Rest House (34° 18′ : 71° 44′)	1,083·9	1,083·0
Ali Jan Kalai (34° 18′ : 71° 45′)	1,067·23	1,065·43
Main Canal, Point 75 (34° 17′ : 71° 47′)	1,099·95	1,099·85
Musa Koruna (34° 13′ : 71° 50′)	986·29	984·66
Zarinabad (34° 8′ : 71° 49′)	925·95	927·78
Ibrahimzai (34° 8′ : 71° 51′)	932·19	932·52
Dosara Canal Rest House (34° 10′ : 71° 53′)	940·85	940·33
Dosara village (34° 9′ : 71° 54′)	925·90	926·57

In the absence of any chemical analyses, one can give no information regarding the quality (hardness, etc.) of the water that will be met with as one sinks a boring here. There is abundant water, however, and it seems only a matter of sinking sufficiently deep to get away from surface contamination to obtain a potable supply. I do not anticipate that it would be necessary to go more than 100-120 feet down, provided every care is taken in the sampling of the water. A reference to item 5 in Table 5 on page 245 shows that tap water at the Charsadda grid sub-station is definitely contaminated bacteriologically.

VI. NOWSHERA AREA.

The Kabul river flows between Nowshera Cantonment and Nowshera City. A bridge of boats and also a rail-cum-road bridge cross this

important stream. During most of the year, the river is sluggish as there is no great fall in level between here and Attock. The sub-soil water level is high about 20-30 feet below ground-evel, and was about 900 feet above sea-level in December, 1938. It varies of course with the rise and fall of the Kabul river.

Sub-soil water level high.

Nowshera Cantonment gets its water-supply from springs in the hills to the south, whence it is piped for distribution. In the hot weather, local people prefer the cooler well water to the hotter piped supply. A reference to Item 7 in Table 5 on page 245 shows that well water in Nowshera Kalan is contaminated bacteriologically.

There can be no shortage of water in the Nowshera area. Abundant sub-surface water will be met by sinking tube-wells and as usual there is doubt only as to the quality of the water. One may bear in mind here that the spring level is some 100 feet above the drainage limit level at Attock. However, there should be little difficulty in obtaining good water before 100 feet depth, provided adequate care is taken in sampling.

VII. RISALPUR AREA.

Risalpur (34° 4′ : 72° 0′) gets its water-supply from a series of wells, with tube-wells, sunk about 500 yards from the Kalpani river above a right-angled bend of that stream over a mile north-east of the Cantonment. There are six wells in all, five being arranged around well No. 2, which is centrally situated and is the main well from which water is pumped and into which water from the other wells is siphoned. Details of the individual wells are as follows :—

Water-supply from wells and tube-wells.

No. 1 well was tested as giving 453 gallons of water per hour. Its reduced spring level is 937 feet, the same as that of all the other wells, as they are interconnected by siphons. The spring level is 26 feet below ground-level. This is an ordinary large diameter well to a depth of 42 feet and there is 53 feet of tube and strainer below its base. The bottom of the tube-well is thus 865 feet above sea-level.

No. 2 well, the main well, was tested to give 6,618 gallons per hour. Its spring level of 937 feet is 31 feet below ground-level and the well is an ordinary large-diameter well for 52 feet, from the base of which there is 80 feet of tube and strainer. The bottom of

the strainer is at 836 feet above sea-level, below which there is a cavity to the reduced level 801 feet.

No. 3 well was tested as giving 503 gallons per hour. Its spring level of 937 feet is 35 feet below ground-level. This is an ordinary well to a depth of 56 feet, *i.e.*, its base is at 916 feet above sea-level.

No. 4 well gave 732 gallons per hour. Its spring level of 937 feet is 41 feet 6 inches below ground-level. It is a 58 feet deep well, below the base of which there is 53 feet of tube and strainer. The bottom of the tube is 865 feet above sea-level.

No. 5 well gave 471 gallons per hour and its spring level of 937 feet is 47 feet below ground-level. It is a 63 feet deep ordinary well with its base at 921 feet above sea-level.

No. 6 well gave 9,660 gallons per hour and its spring level of 937 feet is 31 feet below the surface. It is an ordinary well for 47 feet, below which there is 103 feet of tube and strainer. The bottom of the tube is at 836 feet, below which there is a cavity to 812 feet above sea-level.

The total tested capacity of these six wells is thus 18,437 gallons of water per hour. Actually this figure is far below the amount that is pumped. The latest figures available show that 9,571,500 gallons were pumped during 355 hours pumping, the average supply thus being approximately 26,950 gallons per hour.

It will be seen that the deepest well of the four tube-wells in the Risalpur pumping station is No. 2, which goes down to 801 feet above sea-level. This is about the level of the drainage barrier at the Attock gorge. However, the water is of good quality.

In the 26th year of working the pumping station, 1936-37, the all-in cost was stated to be As. 8·47 per 1,000 gallons of water pumped. This relatively high figure included a major overhaul of one of the two 20·8 H. P. pumps that are installed.

The following are details of the head:—

	Feet.
Suction (static)	13
Suction (friction)	2
Delivery (static)	120
Delivery (friction)	30
TOTAL HEAD .	165

Little further need be stated about the water-supply of the Risalpur area. It has been shown that a suitable source of supply

can be obtained from large-diameter wells, assisted by tube-wells, sunk in *pakka* land (not subject to flood) on the side of the Kalpani river, and this method may well serve as a model for Mardan.

VIII. MARDAN AREA.

It seems strangely anomalous in these days of modern development that the town of Mardan-Hoti with the Civil Lines and Military Cantonment of Mardan should not be supplied by any piped water scheme. The local inhabitants usually either drink the Kalpani water or the more bacteria-infected water of the surface wells, the spring level of which is but a few feet below the surface. There seems to be one well in the Civil Cantonment that was tested to be free from infection—this is the well in the S. D. O., P. W. D.'s compound situated near the edge of the *pakka* land bordering the Kalpani. Many local inhabitants draw their supplies from this well, and as the utensils by which water is drawn cannot be free from infection, even the water of this well must be subject to suspicion. Many officers and their families frequently get their supplies of water from outside stations such as Nowshera, Malakand (34° 34′: 71° 56′) or even Peshawar, which they happen to visit in the course of their duties. Alternatively they may arrange for regular supplies by bullock-cart from Nowshera or Risalpur. From time to time, various schemes for the water-supply of this area have been mooted, but the determining factor seems to be lack of money.

No piped water-supply.

In August, 1936, the Assistant Commissioner, Mardan, wrote to the Officer Commanding the Station, Mardan, stating that the Municipality had under consideration a proposal to lay in water from electrically driven tube-wells to supply Hoti-Mardan city and asked if the Military authorities would join in with the scheme. The Officer Commanding replied in January, 1937, that however desirable such a scheme might be, it could not, for financial reasons, then be initiated either alone or in combination with a Civil authority.

History of proposed schemes.

Meanwhile, Major W. G. Lang Anderson, Executive Engineer of the Mardan Division at that time, had in December, 1936, worked out a scheme to put in a tube-well, high-level tanks and pump to give a good piped water-supply throughout the Civil Lines in Mardan.

Experimental tube-well.

He contemplated the delivery of 24,000 gallons of water per day or 1,000 gallons per hour of continuous pumping. With a head of 150 feet, only 1 or 2 H. P. would be necessary. Work was started about February, 1937, and in five months a 3½-inch tube-well was sunk in the Divisional Officer's compound. The strata met with in this important experimental well are given in Table 3 below :—

TABLE 3.—*Geological strata met with in the experimental tube-well sunk in the Divisional Officer's compound, Mardan.*

Depth.				Thickness.		Strata.
From. Feet.	From. Inches.	To. Feet.	To. Inches.	Feet.	Inches.	Approximate ground-level, 1,014 feet above sea-level.
0	0	30	0	30	0	Hard clay.
30	0	42	0	12	0	Mud.
42	0	50	0	8	0	Hard clay.
50	0	56	0	6	0	Clay mixed with a little sand.
56	0	60	0	4	0	Very hard whitish clay.
60	0	75	0	15	0	Very fine dark-slate coloured sand.
75	0	75	6	0	6	Very hard white clay.
75	6	76	6	1	0	Clay mixed with fine sand.
76	6	78	6	2	0	Hard yellowish white clay.
78	6	79	2	0	8	Very hard clay.
79	2	80	8	1	6	Clay mixed with sand.
80	8	81	2	0	6	Coarse sand with very few small pebbles.
81	2	87	2	6	0	Hard whitish clay.
87	2	98	2	11	0	Sand mixed with little clay.
98	2	99	2	1	0	Hard whitish clay.
99	2	100	2	1	0	Clay mixed with little sand.
100	2	101	2	1	0	Hard whitish clay.
101	2	103	2	2	0	Clay mixed with sand.
103	2	107	2	4	0	Hard whitish clay.

Depth.				Thickness.		Strata.
From. Feet.	From. Inches.	To. Feet.	To. Inches.	Feet.	Inches.	Approximate ground-level, 1,014 feet above sea-level.
107	2	108	2	1	0	Sand.
108	2	111	2	3	0	Hard yellowish clay.
111	2	119	2	8	0	Clay mixed with very little fine sand.
119	2	124	2	5	0	Hard yellowish clay.
124	2	134	2	10	0	Very hard yellowish clay.
134	2	134	8	0	6	Sand.
134	8	148	8	14	0	Soft yellowish clay.
148	8	160	8	12	0	Soft yellowish clay with little sand.
160	8	170	0	9	4	Dry hard clay.
170	0	175	0	5	0	Hard clay but little moistened.
175	0	183	0	8	0	Moist clay mixed with sand.
183	0	192	0	9	0	Hard clay.
192	0	195	0	3	0	Sand.

Fine sand was met with at 192 feet and the water rose suddenly to four feet below ground-level (the sub-soil water level at the time). The rise and fall of water in the boring is shown in Table 4 :—

TABLE 4.—*Depth of water-level during the sinking of the $3\frac{1}{2}$-inch tube-well in the Divisional Officer's compound, Mardan.*

Depth of boring at which observation was taken.	Depth of water-level.
Feet.	Feet.
4	4
120	4
140	58
160	Dry
172	164
180	174
186	182
195	4

The results of the bacteriological examination of the water from this experimental tube-well and of other Mardan water are given in Table 5. Boring was continued to 195 feet when the manilla rope holding the *booki* or excavating tube broke and the *booki* fell to the bottom with some 60 feet of rope attached. About 40 feet of this rope was extricated when the unfavourable report on the water was received. Only 9½ feet of the pipe was recovered and then the remainder was left in the boring as the cost of labour was four times the cost of the tube. The total cost of the experimental tube-well was Rs. 754. Another sample of water from this tube-well was taken a month after boring had finished and examined bacteriologically with the results given as item 6 in Table 5.

TABLE 5.—*Bacteriological examination by the Assistant Director of Public Health, N.-W. F. P., of samples of water from Mardan, Charsadda and Nowshera.*

Item.	Date of sample.	Result after 24 hours' incubation in MacConkey's media.	Colonies on agars.	Opinion and remarks.
1	14-6-37	No change in 100 ccs. and below of sample water.	*Nil.*	Good.
2	14-6-37	Acid and gas in 0·1 cc. and upwards of sample water.	Innumerable	Water from both of these sources is bad and should be boiled or chlorinated before used for drinking purposes.
3	14-6-37	Acid and gas in 0·1 cc. and upwards of sample water.	Ditto	
4	10-7-37	Acid and gas present in 10 ccs. not present in 1 cc.	Ditto	Water is unfit for drinking purposes. It should be boiled or chlorinated before use.
5	17-7-37	Acid and gas present in 0·001 cc. of sample.	Ditto	Ditto.
6	12-8-37	Acid and gas present in 10 ccs. but absent in 1 cc.	Ditto	It is impure water and should be boiled or chlorinated before use.
7	5-9-38	Acid and gas in 10 ccs.	Ditto	Ditto.

Item 1.—Well water, depth 30 feet, S. D. O., P. W. D.'s compound.
Item 2.—Kalpani river water.
Item 3.—Water from tube-well in Divisional Officer's compound, depth not stated but possibly 172 feet.
Item 4.—Water from same tube-well, depth 192 feet.
Item 5.—Tap water of Hydroelectric sub-station, Charsadda.
Item 6.—Water from tube-well in Mardan, depth 192 feet.
Item 7.—Nowshera Kalan well water.

This 195-foot tube-well at Mardan is most informative from a geological point of view. It shows that in this part of the valley of the Kabul and its tributary the Kalpani river, we have predominantly clayey beds to at least 192 feet below the surface, or 822 feet

Analysis of results of tube-well.

above sea-level. It is rather a pity that the boring stopped at 195 feet (the size of the bore was obviously too small to go further even if an accident had not occurred), as it would be very interesting to know the thickness of the water-bearing sand and the nature of the strata below it. One would expect to find these predominantly more sandy, becoming coarser with depth, until finally shingle will be met with overlying the basement rocks.

I have stressed previously (page 234) my doubt regarding the contamination of the water actually coming from a depth of 192 feet in this tube-well (of course I do not doubt the bacteriological examination but the method of sampling). It would seem that sufficient pumping (was any pumping actually carried out ?) before sampling was not undertaken, with the result that the 192-foot water was contaminated by surface sub-soil water. In addition, as has been noted on page 245, the last sampling of the 192-foot water was not done until a month after the completion of the boring, during which time there was abundant opportunity for the water to be contaminated by surface sub-soil water, especially as the spring level rose to four feet from the ground. It must also be remembered that twenty feet of rope was present in the well and could assist contamination by its decomposition.

One last point to be noted is that water from 192 feet, or reduced level 822 feet, is from about the same level (800 feet) as the limiting drainage level at the Attock gorge. Below this level the water is likely to be harder than water from the intermediate levels.

Improvement of drainage essential accompaniment of water-supply scheme.

In early May, 1938, Colonel E. W. C. Noel, Deputy Commissioner of Mardan, wrote to the Civil Surgeon of Mardan reviving the question of the water-supply for Mardan, stating that proposals in the past had been held up on the grounds that no water-supply scheme could be put in without a proper system of drainage. He added :--

"*Primâ facie* I cannot understand why any drainage is an essential preliminary to a water-supply scheme. There are 27,000 inhabitants in Mardan and if we arrange to give them a supply of 16 gallons per day per head and assume that the whole of this water runs out into the drains, then it would only be equivalent to a rainfall of 1-30th of an inch. Moreover every house in Mardan has a well in which the level of the water is on an average of 8 to 9 feet below the surface. It will, therefore, seem that up to now the inhabitants of Mardan have been taking as much as 16 gallons a head per day from wells for their use.

In these circumstances I do not see how a pipe water-supply giving 16 gallons a day per head of population can make drainage any more of a problem than it has been up to now."

Rai Bahadur H. C. Gupta, Civil Surgeon, Mardan, replied that though he did not believe drainage to be an "absolute necessity" prior to a water-supply scheme, it is an "essential accompaniment" of it. He added that :—

"I am definite that the sanitation of the Mardan area, which is already in a hopeless state, is liable to get much worse if all the water as we could naturally assume is allowed to run into the present drains without any proper drainage scheme brought into operation."

He was of the opinion that the drainage would cost about a third of the cost of the water-supply scheme.

Proposed tube-well scheme.

Colonel Noel later wrote to the Secretary to the Government of the North-West Frontier Province reviving the question of a piped water-supply for Mardan. He noted that the local inhabitants like the Kalpani water in preference to well water and added :-

"The objections to the use of the Kalpani are on account of the heavy expense entailed in the filter beds, chlorination plant and settling tanks which are thought necessary because the Kalpani water is always contaminated by surface drainage, and is at times heavily silt-laden. The solution which has suggested itself to me is to put down a tube well in the bed of the Kalpani itself. This is presumably sand and will act as a filter bed, and obviate the necessity of settling tanks. It might also enable us to do without a chlorination plant. The question here, however, rises of the depth of the sand layers. We do not want to go down through a clay and tap the same water that supplies the present wells. If the sand layer in which we hope to get the Kalpani water is say only 20 feet deep it might seem difficult to get the quantity of water we require for the town's needs, *i.e.*, about 8 cusecs. I would propose to overcome this difficulty by putting in a battery of tube wells each say 20 feet and connected up to one pump. This is the method employed for getting drinking water out of the bed of the Luni at Kulachi[1] and which has now been working for 6 years successfully.

The immediate need is to put down a trial bore to test the water from successive depths and see if a clear water is obtainable when the Kalpani is in flood. Could the P. W. D. assist?"

Mr. A. Oram, Chief Engineer, P. W. D., stated that he understood that the Municipal Committee have proposals which have been or are about to be "vetted" by Mr. Howell, Superintending

[1] 31° 55′ : 70° 28′, in the Dera Ismail Khan district.

Engineer, Public Health Circle, Lahore. He added that Colonel Noel's

"idea of tube wells in the bed of the Kalpani may prove to be the solution. The possibilities of this may be limited and will need to be very carefully investigated to avoid disaster.

The depth of shingle and sand above the maximum scour level in the Kalpani bed probably varies a lot and is liable to be cleaned out during the rare big floods which seem to happen once in 10 to 15 years.

Tube Wells, therefore, would be practicable only at a site where the existing sand and shingle deposit is fairly deep and where it could be protected from being wiped out by occasional rare floods without restricting the water-way necessary to such floods."

I give in Table 6 below the flood discharge of the Kalpani river for the last 15 years :—

TABLE 6.—*Flood discharge of the Kalpani river for 15 years.*

Year.	Discharge in cusecs.
1922-23	125,937
1923-24	129,206
1924-25	37,461
1925-26	17,240
1926-27	47,265
1927-28	..
1928-29	46,260
1929-30	10,440
1930-31	..
1931-32	..
1932-33	11,574
1933-34	33,372
1934-35	69,191
1935-36	12,157
1936-37	3,651

It was estimated in June, 1938, that it would cost about Rs. 217 for testing the water in the Kalpani at depths of 10, 15, 20, 25, 30, 35 and 40 feet.

In October, 1938, the Brigadier commanding at Mardan stated that the question of a piped supply of water for the Cantonment was under consideration, but I understand that the matter is in abeyance.

This rather lengthy account of the various schemes for the water-supply of the Mardan area has been necessary in order to appreciate the present position of affairs. Up to now (December, 1938), Mr. Howell has not paid his visit and matters seem at a standstill. However, the following observations may be of value when a combined scheme for the water-supply of the Civil Lines and Military Cantonment and of Mardan-Hoti town is reconsidered.

Recommendation for the water-supply of the Mardan area.

There seems little doubt that the most suitable spot for a supply of sub-surface water from the Kalpani is about half a mile E. N. E. of milepost 17 on the Baghdada-Dargai road as shown on sheet 43 B/4, just north of the well of the Sant Karam Singh. Here there will be little difficulty in protecting wells sunk in the gravels and sands of the Kalpani and the stream channel seems fairly constant. This cannot be said of the channel of the river nearer Mardan. Thus the stream is actively eroding the eastern (left-hand) bank near the causeway between Baghdada and Mardan that leads to Katlang. If wells are sunk on the western (right-hand) bank of the Kalpani, I fear that the supply of water in the gravels will decrease as the stream proceeds further and further to the east. Any site in the gravels of the Kalpani below the causeway would be objected to by the Public Health authorities, as here hundreds of cattle are watered daily. Even if chlorination is necessary at the Sant Karam Singh site, the users of the water-supply would be much happier in the knowledge that they are drinking water far less contaminated than water taken from a site nearer Mardan. So although the Sant Karam Singh site will necessitate two miles or more of ten-inch main, I consider it very advisable to obtain the water from here and not nearer Mardan.

There are two alternative methods available for getting water from the proposed site.

The first method is to have three or four interconnected large diameter tube-wells of relatively shallow depth (less than 250 feet) in the *kachha* land (subject to flooding but not in the main channel of the stream) to the north-east of the well referred to above. The diameter of the tube-wells would be chosen with regard to the

quantity of water it is required to pump. Although the sand and gravel of the Kalpani will be relatively shallow in depth, I see no reason why the supply should not be augmented by tapping deeper water from under protective clay beds, as I feel confident that careful sampling will prove this water to be uncontaminated. The tube-wells could thus have strainers in their upper part (under 50 feet) to tap the upper water under the Kalpani that is filtered through its sandy bed, and lower strainers (up to about 200 feet or less) that would tap possibly the same water-bearing stratum that was met in the well of the Divisional Officer's compound in the experimental tube-well at Mardan. If a scheme such as this were adopted, care would have to be taken to protect adequately the tube-wells and the pumping installation from the rare big floods experienced by the Kalpani.

The second alternative method would be modelled on the lines of the Risalpur water-supply scheme and would have say three large-diameter wells, one 20 feet[1] or more and the others 15 feet, interconnected by siphons and sunk on the edge of the *pakka* land (not subject to floods) just to the north of the well of the Sant Karam Singh. All three wells would have tube-wells within them to tap the lower water-bearing strata that should be met with under 200 feet. This is the method I am inclined to prefer. The large-diameter wells would be sufficiently deep to tap the upper sub-surface water of the Kalpani that would have passed through its sandy bed by natural filtration, *i.e.*, about 50 feet.

The scheme to be adopted must be decided by the engineers concerned, after taking various constructional considerations into view. In any case, however, it would seem very advisable to sink two six-inch experimental tube-wells in this vicinity, one on the *kachha* land north-east of the Sant well and the other on the *pakka* land north of the Sant well. The logs of both tube-wells should be carefully kept for comparison with that of the Divisional Officer's well. Both should be continued to the first large water-bearing stratum met with under the predominantly clayey beds below the Kalpani gravels. This should be well under 250 feet in depth, possibly about 190 feet odd. Samples of the water met with should be very carefully taken after adequate pumping to ensure the origin and depth of the water sampled, and submitted not only

[1] Colonel Noel estimates a supply of 15,700 gallons of water per hour from one 20-foot well, which would perhaps suffice.

for bacteriological but also for chemical analysis. It may be that sufficient water will be met with under 50 feet to avoid the necessity of tapping the deeper water-bearing strata. In any case, I am confident that a solution of the problem for the water-supply of the Mardan area will be found in the site that I have indicated and in one or other of the methods described.

One must, however, bear in mind the suggestion made to me by Mr. G. A. M. Brown, Superintending Engineer, Northern Circle, P. W. D., for the utilisation of the irrigation water of the Mardan Distributary of the Lower Swat Canal. A fall in the level of this distributary is at present used for the generation of electricity for Mardan and would seem sufficient for the installation of a series of filter beds. Utilisation of this source of supply of water would of course necessitate the continuance in the supply of water through the Lower Swat Canal for the whole year, a point that would have to be decided by the Canal authorities. The power house is on the western side of the railway, but the filter beds would possibly better be established on the eastern side. I would prefer to use the Kalpani water as advocated above, but it may or may not be feasible to utilise the Swat water.

IX. AREAS NORTH OF THE MACHAI BRANCH OF THE UPPER SWAT CANAL.

The Upper Swat canal.

Water for the Upper Swat canal is taken from the Swat river at Amandarra (34° 37′ : 71° 59′), some five miles north-east of Malakand in the Dir, Swat and Chitral tribal territory, the canal headworks being at reduced level 2,152 feet. The Upper Swat canal flows under Malakand through the muscovite-granite on which that station is built by means of the Benton tunnel. Formerly all the water discharged from the Benton tunnel into the Mazah Khwar, which stream it followed for about a mile before being channelled again as the Upper Swat canal. Recently, the Hydroelectric tunnel was constructed practically in continuity with the Benton tunnel, and a certain part of the water flows now through this new tunnel, in the schistose rocks bordering the granite and is then dropped 250 feet at Jabban (34° 33′ : 71° 55′) to generate electricity for the Malakand hydroelectric scheme, which will eventually supply cheap power to the whole of the Peshawar and Mardan districts and part of the Kohat district of the Frontier Province and possibly, also,

to the Attock district of the Punjab. This water rejoins the Mazah Khwar before the recommencement of the Upper Swat canal. During the month or so in winter when the canal is closed for repairs, the water is allowed to continue down the Mazah Khwar to the Baghiari Khwar and thence to the Kabul river by means of the Kalpani river.

Just below Dargai Fort (34° 31′ : 71° 54′), the Upper Swat canal branches into two. One branch, the Abazai branch, irrigates mostly the Charsadda tahsil of the Peshawar district and goes westward towards Abazai Fort (34° 19′ : 71° 36′); but it ends about nine miles from that Fort.[1] The other and more important branch, the Machai branch, goes eastward past Machai (34° 15′ : 72° 18′) and on to near Gohati (34° 10′ : 72° 25′), where it splits into three sub-branches, the Pihur, Indus and Maira branches. We are especially interested in that area to the north of the Machai branch of the Upper Swat canal between Kharkai (34° 30′ : 72° 1′) and Machai, which may be considered as four valleys, those of Kharkai, Khui Barmol, Upper Katlang and Upper Rustam. These are more or less typical of most areas north of the Upper Swat canal and the methods of utilising their subterranean water-supply are generally applicable to other similar areas.

Kharkai valley.

The watershed of the Kharkai valley is formed by the semi-circular range of hills to its north. These are mostly formed of ? Palæozoic schists, with subordinate outcrops of Carboniferous massive limestone. The general "dip" of the schists is to the south-east. The valley deposits are mostly the usual very fine-grained 'lacustrine' clayey material, with interbedded gravels, practically flat-bedded, and capped with coarse boulders and shingle in places, in which the present streams have entrenched themselves.

The catchment area of the Badi Khwar above Kharkai is small, being about two square miles. That of the Kuzmai Khwar, which flows to the west of the village, is about double this area. However, there is little doubt that the underground water-supply can be tapped and the position of the villagers alleviated by the construction of two tube-wells, one about half a mile north by west of

[1] The Lower Swat canal takes off from the Swat river at Abazai Fort and irrigates much of the Charsadda tahsil of the Peshawar district and the Mardan tahsil of the Mardan district.

the village (or, alternatively lower down the Kuzmai Khwar) and the other in the bed of the Badi Khwar just south-east of Kharkai.

Khui Barmol valley.

The case of the Khui Barmol (34° 29′ : 72° 7′) valley is more interesting than the foregoing as here the drainage is more confined and there is quite a good chance of a deep tube-well meeting water under sufficient hydrostatic head to bring almost, if not actually, to the surface. The Khui Barmol valley is drained by the Khui Khwar, itself a tributary of the Changa Khwar, which for part of its course forms the boundary with the tribal territory of the Dir, Swat and Chitral Agency. Much of the semicircular range of hills which forms its watershed is composed of thin-bedded limestones which apparently pass up more or less conformably into the Carboniferous massive limestones. They are underlain by ? Palæozoic schists similar to those in the Kharkai area. The valley deposits are likewise similar to those in the Kharkai valley, but the area seems to have undergone considerable recent elevation. Thus whilst Khui Barmol is 1,586 feet above sea-level, the valley deposits rise in the catchment area to over 2,027 feet above the sea, an average rise of about 1 in 60 for some five miles. The alluvium in the Roshagai Khwar, a tributary of the Changa Khwar north of the watershed of the Khui Khwar, is under 1,700 feet above sea-level. The total catchment area of the Khui Khwar above Khui Barmol is about 14 square miles.

With an average annual rainfall of 12 inches and assuming that only one-twelfth of the rainfall feeds the underground water-supply, there is a potential average annual amount of 14,520,000 gallons of water for each square mile of catchment area. With a catchment area of 14 square miles, this means a supply of at least 23,200 gallons of water per hour, provided all the water is tapped. However, the available quantity of water is possibly much larger than has been given, since the annual rainfall is more likely 15-20 inches, and the fractional part of one-twelfth assumed for the percolation is very conservative.

There is always water at Khui Barmol in the wells there, but it is at a depth of 100-160 feet, too deep to be utilised except for drinking purposes. I would suggest the sinking of a deep tube-well just north of Khui Barmol in the hope of striking a water-bearing gravel bed in which the water will be under sufficient hydrostatic head to bring it to the surface, or nearly so. The conditions

seem very favourable, and provided that solid basement rock is not met with before then, a tube-well of some 300-400 feet depth might quite easily pierce an overlying relatively impermeable clayey bed and thus give access to the surface of water under pressure in a gravel bed beneath.

The initial great depth of the water at Khui (say 130 feet) and the slope of 1 in 60 would necessitate a *karez* of about 1½ miles length, were this method of tapping the water adopted. This is of course small compared with the length of some *karezes* that I have seen in Baluchistan.

Upper Katlang valley.

Katlang (34° 21′ : 72° 5′) is situated just below the Machai branch of the Upper Swat canal before it enters a tunnel through the south-westward continuation of the Matta Sar range of hills, which runs diagonally N. E.-S. W. across one-inch sheet 43 B/3. This range of hills is composed of massive limestones overlying thin-bedded limestones and then schistose rocks. The famous Kashmir Smats caves of archæological interest are in the massive limestones between Mian Khan (34° 27′ : 72° 10′) and Pirsai (34° 25′ : 72° 15′). The north-western slopes of this range of hills drain into the Loe Khwar. The villages of Matta, Shamozai and Babozai nestle in its foothills and further to the north are Mian Khan and Sungau, the Loe Khwar having its channel between these last two villages. The total catchment area of the Loe Khwar must be about 50 square miles.

The Loe Khwar is incised in the usual fine-grained, clayey, lacustrine deposits and shows evidence of fairly recent elevation. The deposits are over 1,861 feet above sea-level north-east of Sungau, 1,718 feet at Sungau, 1,638 feet at Mian Khan and about 1,330 feet above sea-level at the Upper Swat canal above Katlang, an average drop of about 53 feet per mile for 10 miles or 1 in 100. However, the drop is more rapid during the first six miles, being approximately 75 feet per mile (1 in 70), and is about 20 feet per mile (1 in 265) for the last four miles.

Water-disputes are very common in the Frontier Province and frequently lead to bloodshed. The springs above Sungau have been a constant source of friction between the inhabitants of Mian Khan and those of Sungau. It would seem possible that most of the difficulties of Mian Khan regarding drinking water would be solved were a deep well sunk in the bed or side of the Loe Khwar just east of the village. Indeed, were a deep tube-well sunk here

it is possible that a sub-artesian flow might be struck; but there are more possibilities of this lower down the course of the Loe Khwar, two to three miles up from the Upper Swat canal.

Upper Rustam valley.

The Land Khwar has a large catchment area above Rustam (34° 21′: 72° 17′) which is only irrigated in the vicinity of the village and upstream as far as Baringanr (34° 23′: 72° 17′). There are several good springs of water issuing from the hills of its catchment area, *e.g.*, near Baroch (34° 25′: 72° 17′)[1] and Pitao Malandrai (34° 25′: 72° 21′), but these are little used. Besides the rocks mentioned as cropping out in the valleys already described, the geology is made more interesting by the occurrence of the very large massif of Buner granite, a hornblende-granite which I have described elsewhere. The effect of the presence of this granite has been to give more permeable deposits than are found in the other valleys.

There is perennial water in the bed of the Land Khwar about a mile above Rustam and Persian wheels are responsible for much irrigation in the immediate vicinity and a short distance upstream of that village. As one proceeds upstream along the various tributaries of the Land Khwar, the water-table is found at an increasingly greater depth below the surface of the Khwar and is generally too deep for irrigation. There are occasional deep wells which give drinking water to various villages, but most of those nearer the hills are fortunately able to get supplies for drinking from springs.

The slope of the valley deposits varies up the different glens which debouch into the Land Khwar. It ranges from about 1 in 40 to about 1 in 200. In the main part of the valley, that towards Pitao Malandrai, where the stream is called the Bakarai Khwar and not the Land Khwar, there are usually valley deposits at two or more levels. The higher of these appear as terraces and they are really the residual lacustrine deposits, formerly more extensive, between which the present drainage system has entrenched itself, and which are being eroded away. The entrenched streams are sometimes as much as 40 feet below the general level of the terraces. From time to time along the courses of the streams draining the area are flat expanses of land at no great height above the present beds of those streams. These are areas where the original valley

[1] Colonel Noel and I measured the main spring at Baroch as being 3·3 cusecs on the 14th April, 1939. It is said never to be less than 0·2 cusecs.

deposits have been removed by the streams changing their courses and relatively recent material has been deposited. Both "terraces" and "flats," as one may call them, are cultivated. The flats near Rustam can be irrigated; but those a fair distance up the valley, *e.g.*, those above Baringanr, cannot be as the water level is too low.

There seems little doubt that apart from harnessing the various springs that are at present mostly wasted, attention could profitably be paid to the underground water-supply and experimental deep tube-well sinking and *karez* digging seem called for, as the following example will show. The Bakarai Khwar bed falls some 300 feet in the first $2\frac{1}{2}$ miles below Pitao Malandrai, an average slope of 1 in 43. I have little information as to the depth of the water-table at point 1,401 feet, $2\frac{1}{2}$ miles below Pitao Malandrai, but do not expect it to be more than 80 feet deep, if as much.[1] A *karez* commenced here and directed upstream would attain a depth of 80 feet in 5·2 furlongs, and will undoubtedly give sufficient water to irrigate the extensive flat just below point 1,401 feet on the left-hand side of the Bakarai Khwar. Although rather far from the Rustam road and so inconvenient for supervision, this would seem a suitable locality to initiate experimental *karez* digging in this part of the Mardan district; but it is most probable that part of the *karez* would have to be lined on account of the numerous boulders that will be met—this will add considerably to the cost of the *karez*.

The terraced land on the other side of the Bakarai Khwar might possibly be irrigated here, were a deep tube-well sunk near the same spot 1,401 feet. As in the Khui Barmol area, such tube-well might easily penetrate a relatively impervious stratum in which the water was under sufficient hydrostatic head to reach, or almost reach, the surface. It certainly seems desirable that an experiment of this nature should be carried out; if successful, the beneficial results to cultivators at present entirely dependent upon rain and dew can easily be imagined.

Little point is served by multiplying instances in a general paper of this character; but I would state that there seem to be other locations within the upper Rustam valley where either *karezes* could be dug, or tube-wells sunk, with very beneficial results.

[1] Water falls from 85 feet below ground-level in winter to 110 feet in July in a well in a new village half a mile W. N. W. of point 1,401 feet. This well is at least 1,430 feet above sea-level, and so water should never be at a greater depth than 80 feet at point 1,401 feet.

APPENDIX.

The Kohat Valley.

Subsequent visit to the Kohat district.

Since the completion of the foregoing paper, I have had occasion to visit the Kohat valley in order to advise on certain water problems in which the Agricultural Department of the North-West Frontier Province was interested, and the following general notes regarding that valley are appended as being of interest in connection with its underground water-supply.

Old scheme for dam at Khwaja Khizar.

An immense amount of water comes down the Kohat Toi and its tributaries and much of this is used for irrigation purposes. A glance at degree (quarter-inch) sheets 38 K and O shows the very large catchment area which this stream possesses; and, accordingly, it is small wonder that generally the level of the water-table in the Kohat valley is high. There was, at one time a scheme for damming the Kohat Toi between miles 15 and 16 from Kohat on the Hangu road. That scheme has apparently fallen into abeyance, but I am uncertain of the reason, perhaps lack of funds. Though the site is far from ideal, there is a strong Nummulitic Limestone ridge on either side of the gorge at Khwaja Khizar (33° 35′ : 71° 13′), dipping upstream. There is certainly the possibility of leaks through fissures in the limestone (a spring seems to issue from the limestone just at the gorge); but it should be possible to dam a very large quantity of water here which would solve most of the problems of irrigation in the lower Kohat Toi valley.

Numerous springs.

The most interesting feature of the area near Kohat is the occurrence of numerous good springs, most of which are shown on the relevant one-inch sheets. These springs are derived from underground water that has had its course interrupted by natural underground dams, generally ridges of limestone. Thus the very large springs near the Fort at Kohat issue against a small ridge of limestone that crops out of the alluvium or lacustrine deposits filling the valley. I shall refer to these springs again.

The soil of the Kohat valley is very similar to that in the Vale of Peshawar, being generally clayey in nature, lightened in places

by the admixture of fine calcareous material from the limestones of the neighbouring hills, and with interbedded gravels. Indeed, the chief rocks in the district are limestones of various ages, Cretaceous and Jurassic limestones forming the border with the Tirah, and Nummulitic limestones cropping out in ridges through the district. It needs no great stretch of imagination to postulate that at several times in its history, during the development of the present drainage system, the Kohat Toi must have been dammed at one or more parts of its course, just as, in the same way, the Vale of Peshawar is thought to have been an immense lake at no very distant period, when the Indus and Kabul rivers were dammed at Attock.

Former lake along the Kohat Toi.

During the damming of the Kohat Toi, whether by earth-movements or other causes, these temporary lakes were filled with detritus, first coarse material and then clayey material; but interbedded with this clayey strata would also be beds of sand and gravel of varying thickness as the different streams debouching into the lakes changed their courses and sites of deposition of coarser material.

At the present time, the Kohat Toi is engaged in eroding away the former lacustrine deposits, mostly impermeable, or only slightly permeable, to water. It was for this reason that I recommended that wells for improving the water-supply of the Jarman estate near Kohat should be sunk in the gravels of the Toi and not in the lacustrine deposits forming its banks.

Possibility of sub-artesian water.

It is hard to give an exact figure for the limiting depth of the alluvium (lacustrine deposits) of the valley of the Kohat Toi. The abundant presence of springs would seem to indicate that there are many underground ridges of limestone at no great depth below the surface. However, in places such as north of Mirozai (33° 33′: 71° 27′) and Bahadur Kot nearby, where there is a fair stretch of lacustrine deposits with no visible indication of the existence of underground barriers, it is possible that if a deep tube-well were sunk, it might strike a water-bearing gravel bed, or beds, in depth in which the water was under sufficient hydrostatic head to rise to the surface, or nearly so, when the overlying relatively impermeable bed or beds were pierced by the bore. I should think it likely that the water issuing as spring water by the Fort at Kohat is sub-surface water of the Kohat Toi travelling along a gravel or boulder bed which abuts upon the limestone ridge at the Fort, and has been

able, fortunately, for Kohat, to find a relatively easy passage to the surface through a fissure in the limestone or through the screes that presumably litter its sides. Were that ridge of limestone not present, that sub-surface water of the Kohat Toi would have a more or less unbroken relatively impermeable covering mantle of alluvium or lacustrine deposit above it and there would be no spring.

Tube-wells limited by individual geological and geographical considerations.

It will be gathered that no general statement regarding the depth of the alluvium or lacustrine deposits in the Kohat valley can be made. Whereas a bore near Bahadur Kot might go 600 feet or more without touching solid basement rock, one situated elsewhere, not necessarily nearer the hills, might strike rock under 100 feet. It must also be remembered that with the deposition of the lacustrine deposits and alluvium, there has probably been concomitant sinking of the basement floor of rock as has been the case with the Vale of Peshawar. Each question of sinking a tube-well in the Kohat valley will have to be considered in the light of its own peculiar geographical and geological circumstances.

Other parts of the Kohat district.

There are many urgent questions of water-supply in parts of the Kohat district other than in the Kohat valley. Though I have not yet had the opportunity of studying these in detail, it would seem that the conditions in many of these areas are greatly akin to those in parts of the Zhob district of Baluchistan and in most of Sind in which I have had considerable experience. In these areas, where the sub-surface water away from the actual stream-courses is generally saline, owing to intense evaporation and the nature of the rocks, it is usually wisest to tap the sub-surface flow of these streams by means of large diameter shallow wells, augmented if necessary by the construction of dry-stone galleries following upstream, or across, underneath their beds.

THE RANGALA METEORITE. BY J. A. DUNN, D.Sc., D.I.C., F.N.I., F.G.S., *Superintending Geologist, Geological Survey of India.* (With Plates 15 to 19.)

CONTENTS.

INTRODUCTION.

The Rangala meteorite fell at about 10 o'clock in the morning of the 29th December 1937. The village of Rangala (25° 23'; 72° 01') is in Jodhpur, Rajputana, and about 30 miles from Bhinmal along a bearing N. 33°W. The first notice of the fall appeared in *The Statesman* of the 25th January 1938—

"On investigating a report that a passing aeroplane had dropped a bomb on a village near Bhinmal, the Jodhpur police came across an apparently authentic case of a meteorite.

The villagers of Rangala state that about 10 o'clock on the morning of December 29, a large object fell out of the sky, and exploded with a terrific noise as it hit the earth. They ran away in a fright, thinking it to be a bomb, but later their curiosity led them back to the place when they found a hole on the ground four feet deep and surrounded with fragments of rock. The stone is grey in colour and very heavy. Samples are being sent for geological report."

The early report as issued by *The Statesman* has proved to be substantially correct except that the size of the crater on impact has since been recorded as 1½ feet in diameter and 1 foot in depth.

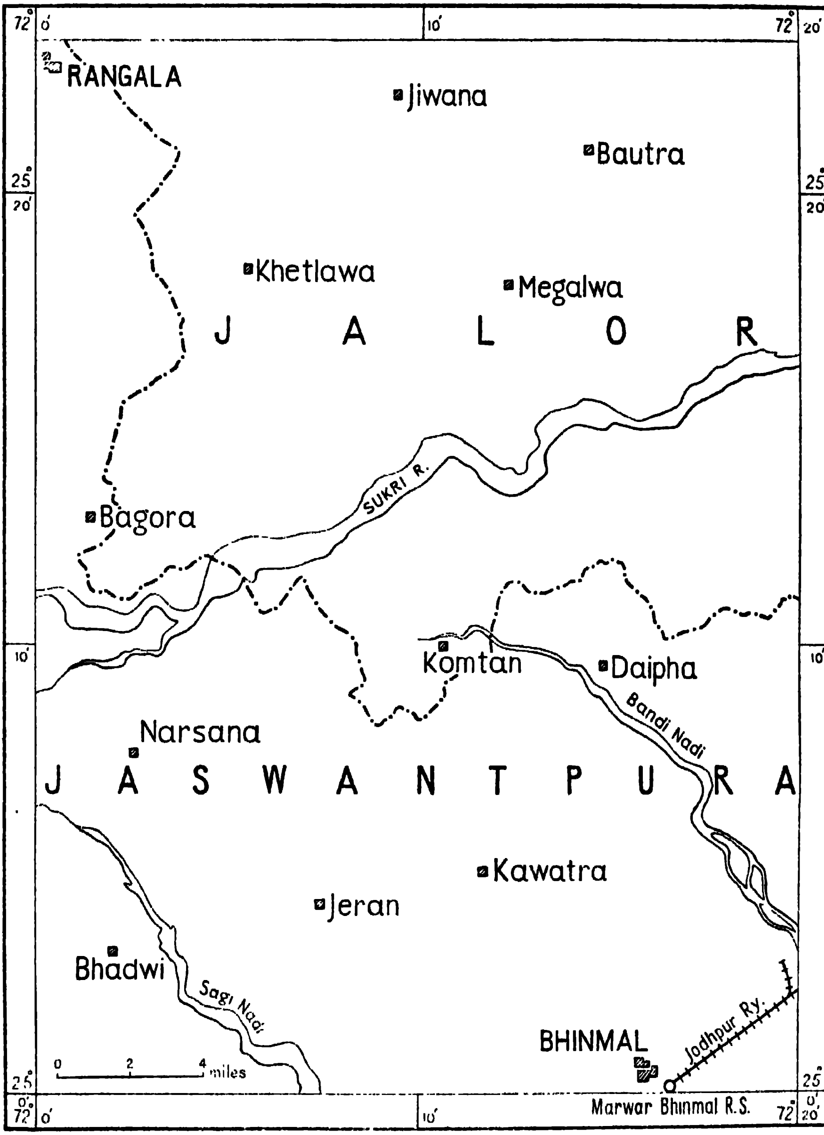


FIG. 1.—Map of the Rangala meteorite locality.

The Inspector-General of Police, in a note to the Chief Minister, remarked that the noise of the meteorite was heard at Bhinmal. He found that the villagers had taken away the fragments of the

meteorite, out of curiosity, but he was able to secure two of them (A and B, Plate 15) which were forwarded to the Chief Minister, Sir Donald Field.

On the request of the Director, Geological Survey of India, the two larger fragments were sent to the Geological Survey with the kind permission of the Chief Minister. Other smaller fragments and powder (C—H) were sent by K. L. Bhola, State Geologist, Jodhpur. Later, during May 1938, eleven more pieces of the meteorite were sent to the Geological Survey by the Jodhpur *Durbar*, a few pieces being retained by the *Durbar* for the local museum.

The meteorite has been registered as No. 320 (A—R) amongst the collection of Stone Meteorites of the Geological Survey of India.

CLASSIFICATION.

The Rangala meteorite is classed as a Veined White Chondrite (Cwa) in Brezina's classification—" white, rather friable mass with scarce, mostly white, chondrules ; black or metallic veins ".

GENERAL DESCRIPTION.

The larger fragments of this meteorite are shown in Plates 15 and 16. The largest measures about 6 inches by 4 inches by 2½ inches, the second largest piece being 3½ inches by 2½ inches by 2 inches. The weight of the fragments received by the Geological Survey of India is as follows :—

	Grams.		Grams.
A	1,670·32-	M_1	66·310
B	532·00-	M_2	31·822
C	41·411	M_3	23·990
D	38·499	N (small grains)	300·300
E	23·633	O „ „	43·475
F	12·982	P „ „	39·755
G (small pieces)	138·665	Q „ „	26·135
H	81·384	R „ „	6·021
I	40·799	Dust	47·775
J	29·816		
K	22·103	TOTAL	3,224·627
L	6·532		

None of the fragments fit into each other; it is apparent that much of the meteorite is missing, and that its size was at least one foot in diameter.

In the primary surface of the larger fragment A, there are several characteristic depressions, and the surface of the meteorite was, apparently, rather irregular. The slaggy crust of the primary surface covers about 5 square inches of the largest fragment A, none occurs on B, but more occurs on one side of each fragment C, D, F, H, I and M_1 and on many of the small pieces and grains. The crust varies in thickness up to about 1·00 mm., its colour is black and the surface is glazed or shiny, but somewhat rough. There are few lines on the surface which could be definitely attributed to movement.

There is no secondary crust, but the meteorite, in a few places, broke along thin veins of metallic minerals and the appearance of this metallic surface is not unlike a secondary crust. Such metallic surface film is usually striated, as if by lateral movement during fracture.

The freshly-fractured surface is greyish white in colour. The meteorite is somewhat friable, and, in making a polished section the amount of bakelite resinoid which it absorbed was rather surprising

The meteorite is fine-granular and contains only a few chondri, the largest of which is only 4 mm. in diameter. Specks of metallic minerals, nickel-iron and troilite, are distinguishable with the naked eye, throughout. In addition, there are numerous thin ramifying veins of nickel-iron. Brownish-yellow specks rapidly appeared over the fractured surface in the Calcutta atmosphere, as a result of oxidation.

I am indebted to Mr. P. C. Roy for the following note on the chemical analyses which he has contributed :—

CHEMICAL ANALYSES.

(By P. C. Roy.)

The procedure for analysis of the meteorite was similar to that described by Prior,[1] differing only in some of the methods of chemical separation, which were done according to the procedure suggested by Ennos.[2]

A fragment (part of No. 230G), free from crust, weighing 12·1047 grams was taken for analysis. The specific gravity of the whole mass taken by suspension in water at 27°C was 3·616. It was crushed and separated by means of a magnet into attracted and unattracted portions weighing 2·20 grams and 9·7047 grams respectively. The results of the analyses are given in Table I.

[1] Min. Mag., Vol. XVII, p. 24.
[2] Min. Mag., Vol. XIX, p. 326.

TABLE 1.

—	Attracted.	Unattracted.	Bulk analysis.	Atomic and molecular ratios.
Fe	44·74	..	8·26	·147
Ni	5·44	trace	1·00	·017
Co	0·78	..	0·14	·002
FeS { Fe	2·27	3·32	3·26	·062
FeS { S	1·30	1·90	1·86	·62
SiO_2	8·42	44·91	40·02	·667
TiO_2	..	0·09	0·08	·001
Al_2O_3	..	2·65	2·27	·022
Fe_2O_3	..	0·58	0·49	·003
Cr_2O_3	..	0·36	0·29	·002
FeO	5·51	15·84	14·59	·201
MnO	..	0·14	0·12	·002
CuO	..	trace	..	..
CaO	0·15	2·40	2·07	·037
MgO	8·89	26·88	24·67	·616
Na_2O	..	0·71	0·61	·010
K_2O	..	0·17	0·14	·001
P_2O_5	..	0·27	0·26	·002
H_2O	..	0·04	0·03	·002
Insoluble	22·49	..	..	..
TOTAL	99·99	100·26	100·16	..

To determine the composition of the olivine, 1 gram of the unattracted material was digested with dilute hydrochloric acid, and gave the following analysis :—

SiO_2	18·05
FeO	11·32
MgO	17·78

The composition of the olivine deduced from this analysis is approximately $3Mg_2 SiO_4$, $Fe_2 SiO_4$.

The mineral composition of the meteorite calculated from the bulk analysis and from the composition of the olivine is given in Table 2.

TABLE 2.

$NaAlSi_3O_8$	5·24		
$KAl Si_3O_8$	0·56	8·86	Felspar.
$CaAl_2Si_2O_8$	3·06		
$FeO.Fe_2O_3$		0·70	Magnetite.
$FeO.TiO_2$		0·15	Ilmenite.
$FeO.Cr_2O_3$		0·43	Chromite.
$3 Ca_3P_2O_8.CaO$		0·67	Apatite.
$CaSiO_3$	2·20		
$FeSiO_3$, $MnSiO_3$	9·37	35·27	Enstatite.
$MgSiO_3$	23·70		
Fe_2SiO_4	12·85	39·32	Olivine.
Mg_2SiO_4	26·47		
FeS		5·45	Troilite.
Fe	8·13		
Ni	1·00	9·27	Nickel-iron.
Co	0·14		
H_2O		0·04	Water.
		100·16	

The above results indicate that the Rangala meteorite belongs to group 3, Baroti type, of Prior's classification. In composition it bears a striking resemblance to the Baroti meteorite as shown by Table 3 :—

TABLE 3.

	Rangala.	Baroti.
Percentage of nickel-iron	9	[illegible]
Ratio of Fe to Ni in nickel-iron	8 : 1	6½ : 1
Percentage of troilite	5	7
Percentage of olivine	39	42
Ratio of Mg to Fe atoms in olivine	3 : 1	3 : 1
Percentage of insoluble silicate	44	40
Ratio of Mg to Fe atoms in enstatite	4 : 1	4 : 1
Percentage of felspar	9	10

An analysis was also made of a small fragment of the crust in order to determine what changes in composition, if any, occurred

at the surface. As will be described later, the crust consists of two well-defined layers—a thin outer selvage of slag, and an inner layer. The latter is further divisible into two zones, an inner in which nickel-iron and troilite veinlets are abundant, and an outer in which they are absent. The analysis is given in Table 4.

TABLE 4.

Fe	7·69
Ni	1·34
Co	0·14
Fe	3·53
S	2·02
SiO_2	38·24
TiO_2	0·08
Al_2O_3	2·014
Fe_2O_3	2·44
Cr_2O_3	N. D.
FeO	15·28
MnO	N. D.
MgO	24·74
Na_2O	0·90
K_2O	0·38
P_2O_5	0·14
H_2O	N. D.
	99·84

Comparing this analysis with the bulk analysis of the meteorite, the most noticeable difference is in the increase of Fe_2O_3—a change to be expected from the development of Fe_2O_3 in the slag as suggested under the microscope. Otherwise, in view of the small amount of crust (with unavoidably attached sub-crust) used for analysis, the differences in the constituents present are so slight that they provide no reliable basis for discussion. All that can be said is that there is no profound total change in chemical composition within the crust as a whole.

PETROGRAPHICAL DESCRIPTION.

Thin and polished sections of the meteorite were studied. Particular attention was paid to the structure of the primary crust some of which was included in one of the thin and polished sections. By careful prior treatment with bakelite the delicate crust was undamaged in both types of section.

THIN SECTIONS (REG. No. 25498).

The silicates.

The silicate constituents of the meteorite, as seen in thin section, call for no particular comment. It is a typical white chondrite, somewhat porphyritic, with a fine-grained granular groundmass and a few rounded chondri and with a rather brecciated structure. Some minute fractures cut the silicates. Olivine is easily the most abundant mineral, occurring as larger individual rounded crystals as well as in the granular groundmass, and in chondri lamellae with enstatite. Some enstatite is present apart from that in the chondri, and also a little clinoenstatite with typical oblique extinction. Opaque minerals are quite abundant. In one section a small grain of an opaque mineral, grey-white by reflected light, is reminiscent of leucoxene, but no leucoxene was observed in either of the two polished sections.

The crust.

The primary crust (Plate 17, fig. 1) is about 1 mm. wide and consists of two parts—(*a*) an outer thin selvage of slag very irregular in thickness, but not greater than 0·2 mm.; (*b*) the crust proper containing black opaque material which replaces and veins the silicates in the crust from crystal interfaces and cleavages.

The slag selvage is opaque black and has a sharp and clean-cut boundary against the crust proper, in contrast with the rather irregular inner boundary which the opaque minerals of the latter make with the body of the meteorite.

The crust proper also consists of two zones. There is an inner zone, 0·6 mm. thick, closely penetrated by opaque material, and along the greater part of the length of the crust in the section the opaque material do not reach the outer surface of the crust, thus leaving an outer zone, about 0·2 mm. thick, consisting of silicates almost free of opaque material.

The three zones—slag selvage, outer zone of crust and inner zone—are shown in Plate 17, fig. 1. This zoning is confirmed in the polished section, where the veinlets of troilite and nickel-iron die out before reaching the outer surface (Plate 19, fig. 3).

POLISHED SECTIONS (REG. NO. 344).

Two polished sections were prepared, one containing a portion of the crust and the other including a vein of nickel-iron.

The metallic constituents.

Five metallic constituents were determined, troilite, two varieties of metallic iron, chromite and copper. Only two minute patches of copper were detected in one of the sections and it is, accordingly, extremely rare.

The nickel-iron alloys so far recorded in nickel-iron meteorites are kamacite and taenite, whilst plessite is presumably an intergrowth of these two. It is not even entirely certain whether taenite is a homogeneous material or a fine intergrowth. According to Borgström, kamacite[1] contains 7 per cent. Ni+Co, taenite[2] about 38 per cent. Ni+Co, whilst the eutectoid, plessite,[3] contains 14 per cent. Ni+Co.

It may be assumed that the iron alloys in the stony meteorites are of similar composition to those constituting the nickel-iron meteorites although this, apparently, has not yet been definitely determined. In the Rangala meteorite two distinct metallic iron substances are present, the one containing no nickel so far as microchemical tests show, the other rich in nickel. As there is no reason to presume that the alloys of the stony meteorites are different from those of the nickel-iron meteorites, I shall refer to the two alloys in the Rangala meteorite as kamacite and taenite respectively. Of these kamacite is easily the more abundant of the two, the proportion of one to the other being perhaps 10 to 1.

Troilite.—The properties of troilite under the reflecting microscope are identical with those of pyrrhotite, the distinctive creamy tint being, however, slightly stronger, perhaps, than for typical pyrrhotite. Along certain lines of stress the troilite has been granulated to an extremely fine aggregate which, because of reflection pleochroism between adjacent grains, is noticeable under high power. The troilite in the crust, containing ex-solution droplets of iron, shows a slightly paler colour than the more normal troilite, possibly due to loss of sulphur.

[1] L. H. Borgström, "On the composition of the metooric nickel-iron alloys and on magnetic lines on sections of meteoric irons", *Fennia* 45 (2), pp. 6-7, (1925).

[2] *loc. cit.*, p. 7.

[3] *loc. cit.*, pp. 14-15.

Kamacite.—Colour : grey-white, with suggestion of blue against taenite. Reflectivity : about 55. Hardness : — D. but noticeably less than taenite and troilite. Polishes with ease. Isotropic.

On etching, occasional elongated s appear, arranged apparently along the octahedral direction. These lamellae are etched to an equal degree with the remainder of the iron, suggesting that they represent twinning there is, of course, the possibility that such lamellae consist of a distinc iron alloy. The fact that they are more abundant c to strain zones favours twinning (Plate 18, fig. 3).

Microchemical tests failed to give the ;htest trace of Ni, even though the tests were made on a relatively considerable amount of the alloy bored out from the polished grains. Although it is probable that a Ni-content of 1 or 2 per cent. may not show up in such a test, the amount in normal kamacite, 7 per cent., would give a clear and positive test. This material is, then, either pure Fe, or is a kamacite rather low in Ni as compared with tha recorded by Borgström.

Taenite.—Colour : grey-white, with a noticeable yellow tint against kamacite. Reflectivity : 60, higher than for kamacite. Hardness : — D, but slightly higher than kamacite and less than troilite. Polishes with ease. Isotropic.

The taenite etches much less rapidly than kamacite—after 20 seconds immersion in 5 per cent. HNO_3 in alcohol the kamacite is greyish black whilst the taenite is bright and unetched. No structure develops on further etching and the material is apparently perfectly homogeneous under highest power.

For microchemical tests no grains sufficiently large to provide material uncontaminated with kamacite or iron silicates could be removed. A strong Ni reaction could always be obtained. Two possibilities emerge :—(*a*) that it is pure nickel, or (*b*) that it is nickel-iron of high nickel content, and probably taenite. In the chemical analysis, the ratio of Fe : Ni+Co is 7·25 : 1. This is rather lower than the relative amounts of kamacite and taenite visible in the polished sections would suggest, but the discrepancy is the least if we regard the two minerals as actually kamacite and taenite and not as pure iron and pure nickel.

Chromite.—Small scattered grains show the tint and reflectivity of chromite. A bead test on powder, excavated from a larger grain than usual, gave a chromium reaction. Although these

grains are usually referred to as chromite in descriptions of meteorites, published analyses indicate a very variable composition, the mineral often containing considerable amounts of MgO, Al_2O_3 and Fe_2O_3; some might be equally well classified as picotite.

Copper.—Two very minute grains in taenite have the characteristic colour, reflectivity and hardness of copper. They become obscured on etching.

Relations of the metallic constituents in the body of the meteorite.

The troilite, nickel-iron and chromite occur mainly as discrete grains (Plate 17, fig. 2). Sometimes the troilite and nickel-iron occur together and troilite, in rare cases, forms a border to the iron. On the whole, the troilite and nickel-iron are interstitial to the silicates.

In some grains kamacite and taenite are closely intergrown (Plate 17, fig. 3), and frequently taenite forms a thin rim around kamacite (Plate 17, fig. 4). Kamacite is easily the more abundant, the proportion being perhaps 10 to 1.

Occasionally, chromite grains are associated with troilite, and veins of the latter have been detected in chromite. No veins of chromite were seen, but sometimes a fine ? chromite dust occurs along microscopic fractures. Chromite is occasionally moulded on both troilite and nickel-iron.

The two extremely minute grains of copper occur in an intergrowth of kamacite and taenite (Plate 17, fig. 3).

Large veins of nickel-iron, mainly kamacite, accompanied by troilite, traverse the meteorite (Plate 18, fig. 1), and appear to replace the silicates at the border of the veins. Troilite clearly forms veins within the nickel-iron veins (Plate 18, fig. 2). The walls of the nickel-iron veins are not clean cut, but are decidedly irregular, following the outline of the bordering silicate minerals, and the opposite sides of the vein are not parallel. The taenite occurs only on the walls of the veins (Plate 18, fig. 3). Etching brings out a strain zone which follows the centre of the vein with slip lines or twinning branching off (Plate 18, fig. 3). This strain zone traverses the length of a troilite veinlet in the iron, and has finely granulated the sulphide.

No *individual* silicate grain is traversed by minute metallic veinlets. The brecciated structure of the silicates is well shown in the polished sections.

Relations of the metallic constituents in the crust.

The polished section confirms the zonal arrangement of the crust, noted in the thin section, but brings to light unsuspected structural changes in the metallic constituents within the crust. Innumerable minute veinlets of troilite and kamacite occur in the inner zone noted in thin section. These veinlets ramify through the inner zone of the crust, but do not extend to the outer zone which contains only silicates and chromite. The outermost slag also contains no troilite or kamacite.

Throughout the meteorite the troilite is quite clear and contains no inclusions of iron. At the inner edge of the crust the troilite suddenly becomes full of ex-solution droplets of iron (Plate 18, fig. 4). Indeed, in one grain of troilite there is a sharp line on one side of which the mineral is clear, but on the crust side the grain contains a swarm of ex-solution iron droplets (Plate 19, fig. 1). In some grains the separation of iron is almost complete, and only a little troilite remains on the border (Plate 19, fig. 2).

Next, the troilite is seen to form minute ramifying veinlets throughout the whole of the inner zone of the crust (Plate 19, fig. 3) cutting across individual minerals, and in these veinlets ex-solution iron becomes more and more abundant towards the surface, until many of the veinlets are entirely of iron. These veinlets all die out at the inner side of the outer zone, their ends following a remarkably regular line (Plate 19, fig. 3).

The thin slaggy or glassy selvage, which covers the crust and is of very variable thickness, is crowded with incipient "feather" crystals and fine dust of a mineral which has a reflectivity rather above that of adjacent grains of chromite, and has the grey tint of hematite (Plate 19, fig. 4). Its identification with the latter mineral is not at all improbable, and is rather confirmed by the analysis of the crust. It is interesting to note that occasional undigested grains of chromite occur in the slag, and even project at the surface.

DISCUSSION.

The division of the crust into three well-marked zones is a characteristic of meteorites. Tschermak explained these zones as due to fused matter which penetrated the middle zone and congealed in the inner zone.[1] The evidence provided by the change in the

[1] O. C. Farrington, "Meteorites", p. 82, 1915, Chicago.

troilite within the crust of the Rangala meteorite indicates that this is not the whole explanation. The thickness of the crust is also said to vary with different meteorites, the more friable and porous meteorites possessing the thickest crusts; to this may be added the probability that meteorites traversing the earth's atmosphere at a low angle acquire a thicker crust than those entering at a steep angle, owing to the longer period of heating and the possibility of a higher superficial temperature. The literature rather indicates also that structural crustal change in iron meteorites goes deeper than in stony meteorites, due, presumably, to the greater heat conductivity and lower fusion temperature of the former.

During the meteorite's flight through the Earth's atmosphere, the heat generated at the immediate surface melted the silicates as a thin skin, and this melt was presumably vaporised and dissipated in the atmosphere. Chromite was, apparently, the last of all the minerals to melt, in fact there is no certainty that it does melt, for, with removal of more fusible silicates around it the chromite would be loosened and stream off as solid dust. The highly irregular outer surface of the slag, as seen in thin sections, is due to flow lines which, in the Rangala meteorite, are imperceptible in the hand specimen.

On impact, the slaggy selvage cooled immediately, and incipient crystals of ? hematite separated out. The probable identification of these incipient crystals with hematite suggests the absorption of oxygen from the atmosphere by the slag; such absorption would, of course, assist the oxidation of the sulphur in the troilite, noted below. The normally sharp and smooth contact between this selvage and the underlying crust is striking.

In consequence of the low heat conductivity of the silicates, and of the dissipation of the selvage of slag during flight, heat transference did not penetrate appreciably below the thin crust, and the centre of the meteorite remained cold. A high-magnesia pyroxene has a melting point over 1,500°C and an olivine of the composition $3Mg_2SiO_4.1Fe_2SiO_4$ has a melting range commencing at approximately 1,550°C and completed at approximately 1,760°C[1]—the slag selvage and the surface skin temperature might, under conditions of rapid heating, approach the latter figure. Within the crust, immediately below the slag selvage, the heat generated was

[1] N. L. Bowen and J. F. Schairer, "The System MgO-FeO SiO_2", *Amer. Journ. Science*, XXIX, figs. 6, 8 and 28. (1935).

insufficient to melt the silicates completely, whereas melting of troilite and iron took place almost throughout the crust. At the inner side of the crust the first mineral to show change was the troilite, the melting point of which is in the vicinity of 1,200°C. Pure iron melts at 1,535°C, but nickel-iron alloys have melting points as low as 1,425°C—the kamacite would have a melting point closer to 1,500°C. Under the low pressure conditions of the upper atmosphere volatilisation would tend to be rapid at temperatures little above the melting point—such a statement of course ignores the fact that the front surface of a meteorite in flight would be under enormous pressure, and the rear side under extremely low pressure, but it would appear that the great majority of meteorites rotate somewhat during flight. The rapid superficial expansion on heating shattered the silicates and chromite within the crust and the molten sulphide and iron streamed into the fractures. The temperature within the outer zone of the crust was sufficient to completely vaporise the iron and sulphur at the low pressure, so that these constituents were unable to form veinlets within this outer zone. It may be deduced that the temperature at the base of the crust was about 1,200°C, increasing to over 1,700°C at the surface, *i.e.*, a range of 500°C in 0·8 mm. The temperature would be approximately zero at a depth of 3 mm. from the surface of the meteorite.

One other deduction from the thickness and structural changes of the crust may be made. It is obvious that at any moment of its flight within the atmosphere, the thickness of the primary crust is never greater than that at impact. The sharp division between slag selvage and crust proper indicates that loss by dispersion in the atmosphere is from an extremely thin surface film. The much thinner secondary crust developed on some meteorites on fresh surfaces exposed by fracture during flight in the atmosphere, indicates that even the thin crust of the primary surface takes a considerably longer period to develop than that for the secondary crust. It is, therefore, doubtful whether any stony meteorite is appreciably reduced in size by loss by dispersion through fusion and vaporisation at its surface from the time of entering the Earth's atmosphere, apart from mechanical losses due to fracturing and disintegration during flight.

With the slowing up of meteorites in consequence of frictional resistance, during their flight through the earth's atmosphere,

it is probable that the surface temperature generated becomes progressively diminished; if the speed is sufficiently retarded the skin temperature may be reduced to far below melting point before the meteorite actually reaches the earth's surface. It is possible, then, for the meteorite surface to be cold at the moment of impact—this will depend on the initial speed of the meteorite and the direction in which it enters the earth's atmosphere. Actual cooling of the crust below melting point, described above as following immediately on impact, may actually have taken place prior to impact. Retardation may explain also the difference in thickness between primary and secondary crusts; it should, indeed, be possible for fractured surfaces to show no crust if fracture took place when the speed was low.

The significance of the breakdown of the troilite may now be discussed. The first change in the troilite at the base of the crust, was loss of sulphur and the appearance of ex-solution droplets of iron. With greater heat the molten sulphide and iron streamed out through fractures. That which was in the fractures on impact, with rapid cooling, remained as veinlets of troilite and iron. It is a matter for speculation whether the development of iron from troilite resulted from simple dissociation or whether the sulphur was burnt off as SO_2 by oxygen absorbed from the atmosphere. The development of ? hematite in the slag selvage suggests the latter possibility, but it is difficult to appreciate how the oxygen could be absorbed down to the inner zone of the crust in the face of the opposing stream of outwardly dissipating S and Fe vapour.

The contrast between the structure of the crustal veinlets and of the larger veins which occur in the body of the meteorite, may throw some light on the origin of the latter veins. Within the crustal veinlets the opposing veinlet walls are parallel, *i.e.*, they fit into each other, whereas the irregular walls of the large veins in the meteorite do not fit each other. The clear troilite of the large veins is in contrast to the swarm of ex-solution droplets in the crustal troilite. The arrangement of the troilite, kamacite and taenite within the coarse veins, described herein, has no parallel in the crustal veinlets. These facts all suggest that the metallic constituents of the coarse veins were in the solid phase at the moment of impact. This is confirmed by the strain zone which traverses the centre of the veins and which was caused presumably at impact, certainly not later.

It might be submitted, however, that these veins represent molten iron and troilite which streamed into fractures in the centre of the meteorite from the molten surface, during its flight through the atmosphere, and that these metallic constituents were immediately frozen within the extremely cold body of the meteorite. But the irregular walls of the veins show that they did not occupy simple fractures, and also there is no sign of those droplets of iron in troilite which indicate rapid separation from a melt and which occur in the crust. Also, the bordering taenite, and the central veinlets of troilite in the kamacite of the large veins, do not suggest a sudden injection and cooling.

It would appear, then, that these veins in the body of the meteorite were in existence prior to its entering the Earth's atmosphere. We have the alternatives :—(*a*) that the veins were in existence whilst the meteorite was still within the original heavenly body of which it is a dismembered fragment, (*b*) that the veins developed after dismemberment of the heavenly body. With respect to the first alternative, its truth rests on the possibilities of veins forming at great depths in the crust of a heavenly body, a possibility against which I see no sound logical objection. In discussing the second alternative two possibilities arises : (i) change in the meteorite immediately on disruption of the original heavenly body and (ii) metamorphism in consequence of varying vicissitudes of temperature environment in its later history.[1] Considering (i) it may be postulated that the heat generated on dismemberment would raise the temperature of the vast cluster of meteorites which would arise, thus changing their physical condition even apart from the sudden reduction of pressure, a change which would mean not only recrystallisation but perhaps even partial melting. Whilst the meteorites remained close to each other in the cluster the temperature would drop slowly until gradually the meteorites drifted further apart. During that period molten constituents would tend to separate out more completely as they crystallised slowly, and fill any fractures which may be present. In consequence of partial melting and recrystallisation such fractures would be unlikely to have regular walls. The changes under (ii) would arise under conditions of temperature similar to those under (i). The

[1] G. P. Merrill, " Composition and structure of meteorites ", *United States National Museum Bull.* 149, pp. 40-45, (1930).

possibility suggested by several authors that the iron may have been derived directly from olivine receives support, perhaps, from recent work by Bowen and Schairer who have shown that these ferrous silicates melt incongruously with separation of iron.[1]

DESCRIPTION OF PLATES.

PLATE 15.—Fragments of the Rangala meteorite.

PLATE 16.—Fragments of the Rangala meteorite.

PLATE 17, FIG. 1.—Thin section, showing three zones in the crust. Zone 1—slag selvage, Zone 2—outer zone of crust proper, Zone 3—inner zone of crust. ×36.

FIG. 2.—Troilite (T), kamacite (K) and chromite (M) in the silicates. ×50.

FIG. 3.—Intergrowth of kamacite (etched dark grey) and taenite (white). Note also troilite (T) and copper (C). Etched. ×720.

FIG. 4.—Kamacite (K) surrounded by a thin shell of taenite (N). Troilite (T). Etched. ×100.

PLATE 18, FIG. 1.—Coarse veins of kamacite (K) and clear troilite (T) in the silicates. Taenite (N). ×50.

FIG. 2.—Veinlet of troilite (T) in the kamacite vein. ×50.

FIG. 3.—Strained centre to the kamacite vein (K). Taenite (N) to one side. Note slip lines or twinning in the kamacite. Etched. ×50.

FIG. 4.—Ex-solution iron (white) in troilite (grey) in the crust. Note branching veinlets of troilite and iron. ×720.

PLATE 19, FIG. 1.—Ex-solution iron on one side of troilite, the other side clear. In the crust. ×720.

FIG. 2.—Troilite around edge of iron, with also veinlets of iron and troilite in the crust. ×720.

FIG. 3.—Veinlets of iron and troilite in chromite (M) and silicates in the crust. Note that the veinlets stop before the outer edge of the crust is reached. ×450.

FIG. 4.—Skeleton ? hematite crystals in the slag selvage. ×720.

[1] N. L. Bowen, and J. F. Schairer, "The system FeO-SiO_2", *Amer. Journ. Science*, 24 (141), pp. 186 *et seq.*, (1932); "The system MgO-FeO-SiO_2", *Ibid.*, 29 (869), p. 157, (1935).

MISCELLANEOUS NOTE.

Quarterly Statistics of production of Coal, Gold and Petroleum in India and Burma, January to March, 1939.

Coal.

—	January.	February.	March.	Quarterly total for each province.
	Tons.	Tons.	Tons.	Tons.
Assam	23,367	24,002	25,371	72,740
Baluchistan	822	1,431	833	3,086
Bengal	645,718	657,837	666,742	1,970,297
Bihar	1,160,997	1,307,653	1,268,970	3,737,620
Orissa	5,054	5,249	5,413	15,716
Central Provinces . . .	154,096	159,306	128,703	442,105
Punjab	16,270	18,321	17,132	51,723
TOTAL .	2,006,324	2,173,799	2,113,164	6,293,287

Gold.

—	January.	February.	March.	Quarterly total for each company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,421	7,622	8,426	24,469
The Champion Reef Gold Mines of India, Ltd.	5,963	5,394	5,975	17,332
The Ooregum Gold Mining Company of India, Ltd.	4,324	4,297	4,507	13,128
The Nundydroog Mines, Ltd. .	8,135	7,339	7,903	23,377
TOTAL .	26,843	24,652	26,811	78,306

Petroleum.

—	Crude Petroleum.	Total Gasolene from natural gas.*
	Gallons.	Gallons.
Assam	16,313,974	*Nil.*
Punjab	8,289,560	143,712
TOTAL .	24,603,534	143,712
Burma	60,313,516	2,639,760

* These figures represent the total amounts of gasolene derived from natural gas at the well head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

MGIPC—M—VIII-1-3—7-11-39—725.

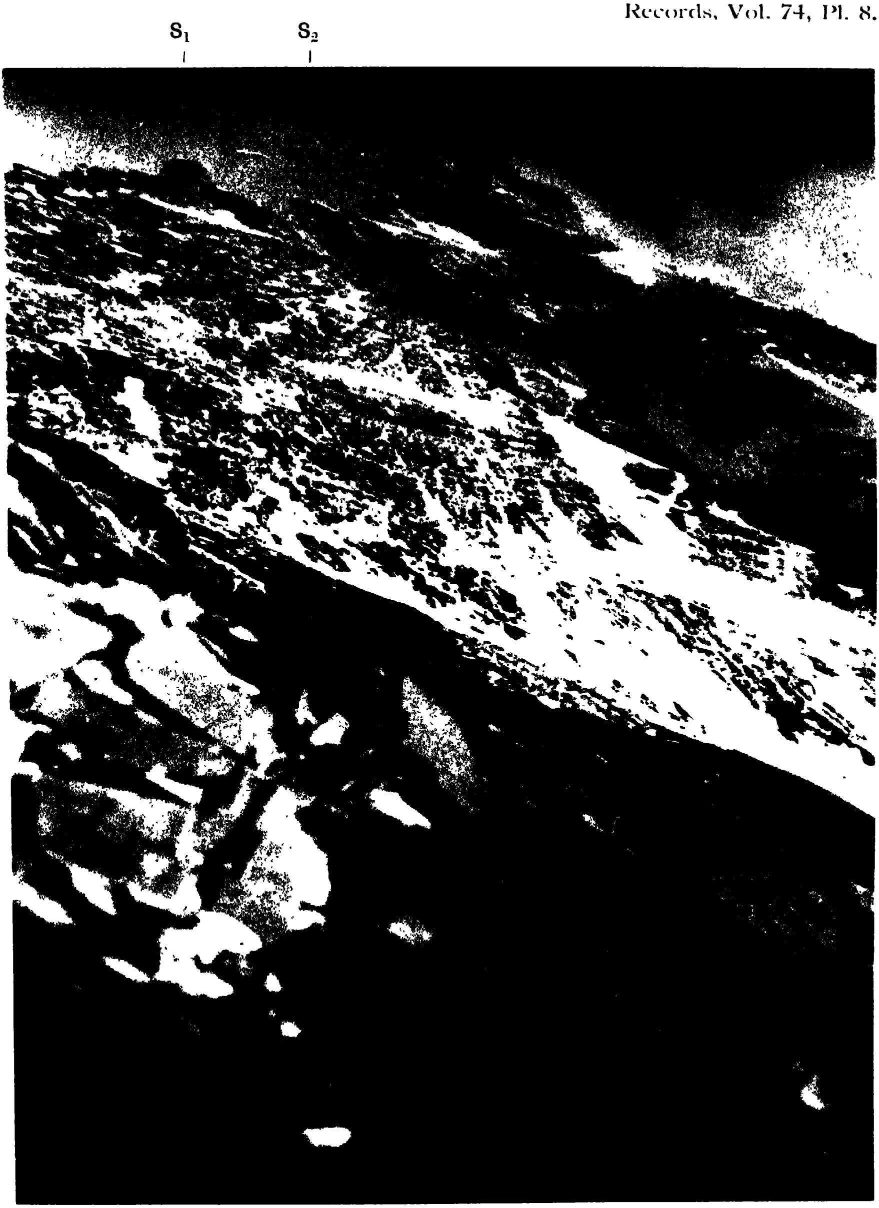
Records, Vol. 74, Pl 7.

G S. I. Calcutta.

LACHI SPUR FROM THE EAST.

F_1—SADDLE ON THE RIDGE AT WHICH IMMATURE CORALS AND A GASTROPOD WERE OBTAINED. F_2—SADDLE ON THE RIDGE AT WHICH UPPER PERMIAN FOSSILS WERE OBTAINED. F_3—APPROXIMATE LOCALITY OF AUDEN'S TRIASSIC FOSSILS. S—SUMMIT OF LACHI. THE JUNCTION BETWEEN MOUNT EVEREST LIMESTONE AND THE UNDERLYING GNEISSES IS TO BE SEEN ON THE LEFT DIPPING NORTH AT 45°.

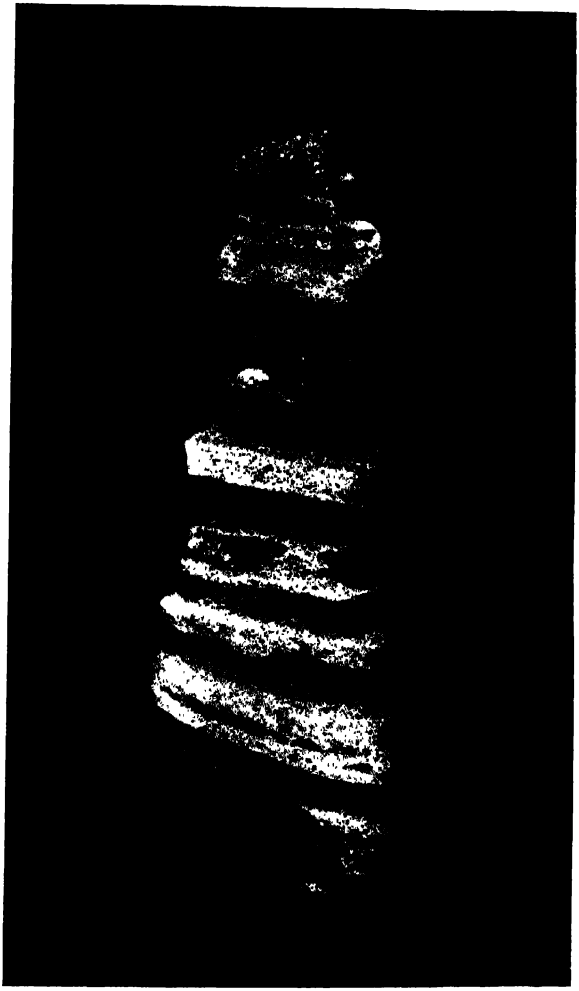
Records, Vol. 74, Pl. 8.



G. S. I., Calcutta.

MOUNT EVEREST FROM 27,000 FEET ON THE N.-W. RIDGE.

MOUNT EVEREST PELITIC SERIES IN THE FOREGROUND; THE YELLOW SLABS IN THE MIDDLE DISTANCE; THE FIRST AND SECOND STEPS (S_1 AND S_2) ON THE SKYLINE COMPOSED OF MASSIVE, ARENACEOUS LIMESTONE OF THE MOUNT EVEREST LIMESTONE SERIES.



G. S. I., Calcutta

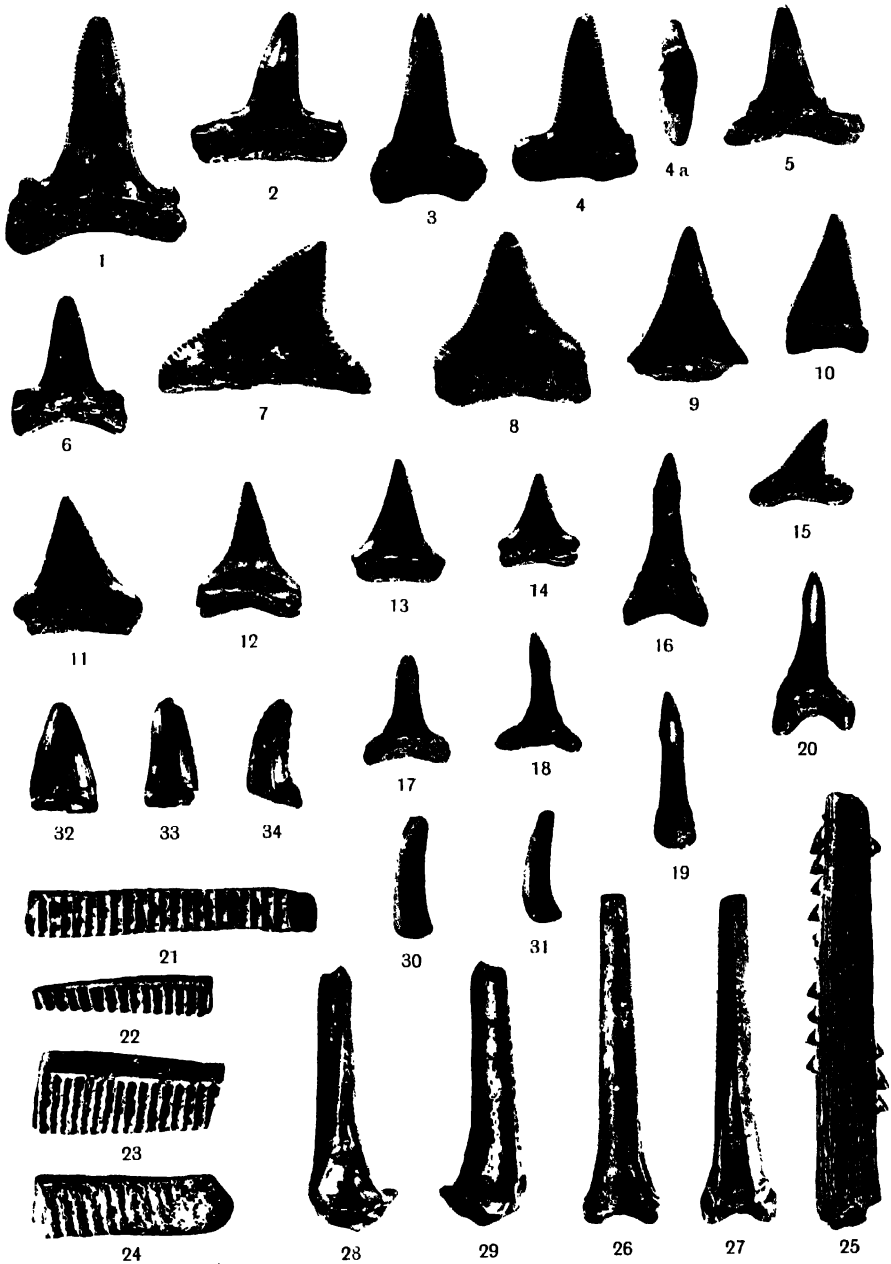
MOUNT EVEREST LIMESTONE.

WEATHERED FRAGMENT, THREE INCHES HIGH, SHOWING RESISTANT BANDS WHICH ARE DOMINANTLY ARENACEOUS.

G. S. I., Calcutta.

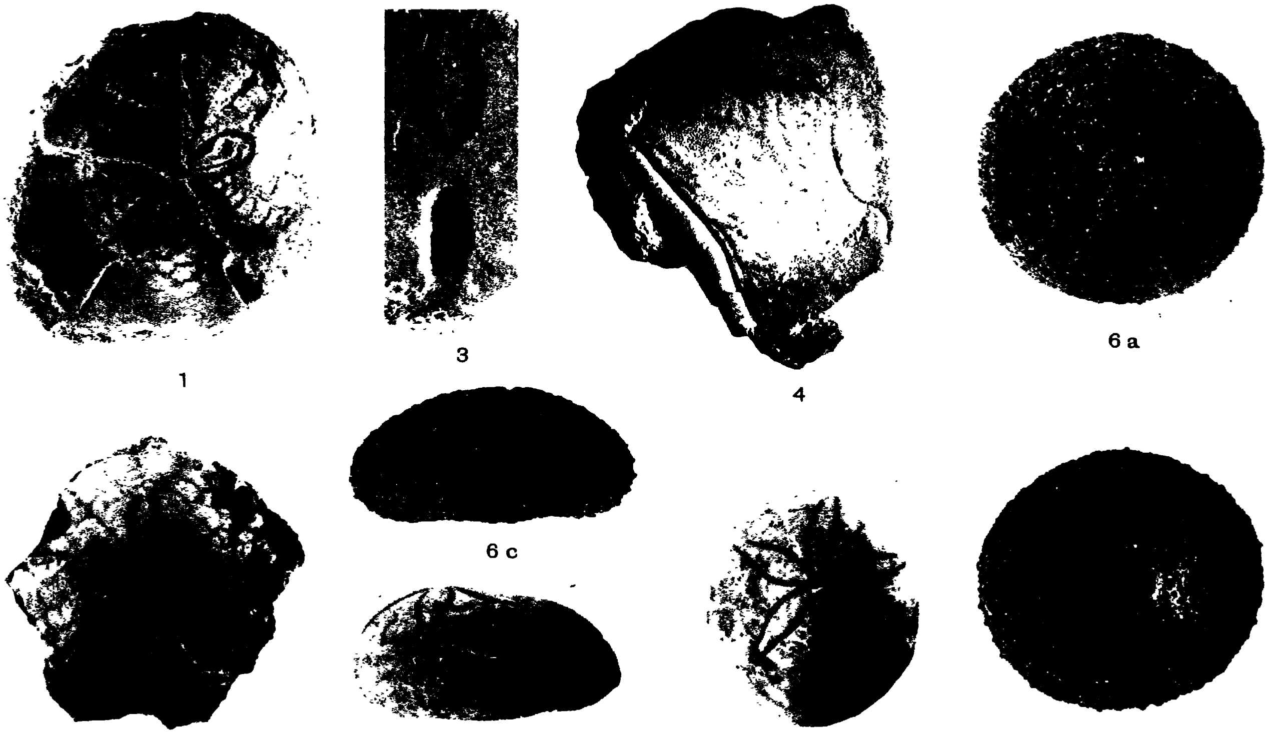
MOUNT EVEREST PELITIC SERIES WITH SILL OF LIGHT GRANITE. 500 FEET THICK, FINGERING OUT INTO *'LITS'*.

N.-E. SIDE OF EAST RONGBUK GLACIER NEAR SNOUT.



S. C. Mandul, Photo *G. S. I., Calcutta*

FOSSIL FISH REMAINS FROM BALASORE.



1 3 4 6 a

6 c

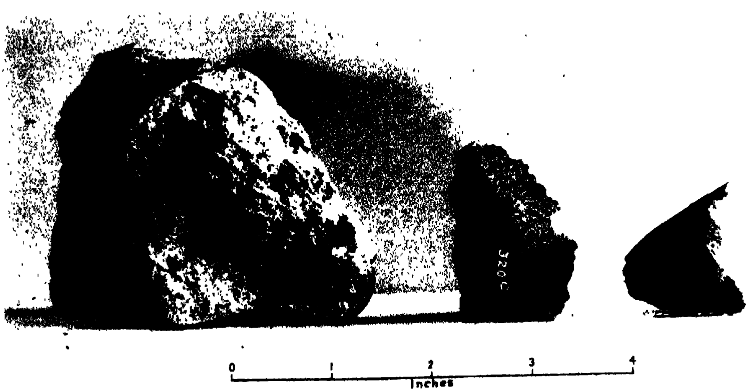
2 5 b 5 a 6 b

G. S. I., Calcutta.

TERTIARY ECHINOIDEA FROM BURMA.

A

A



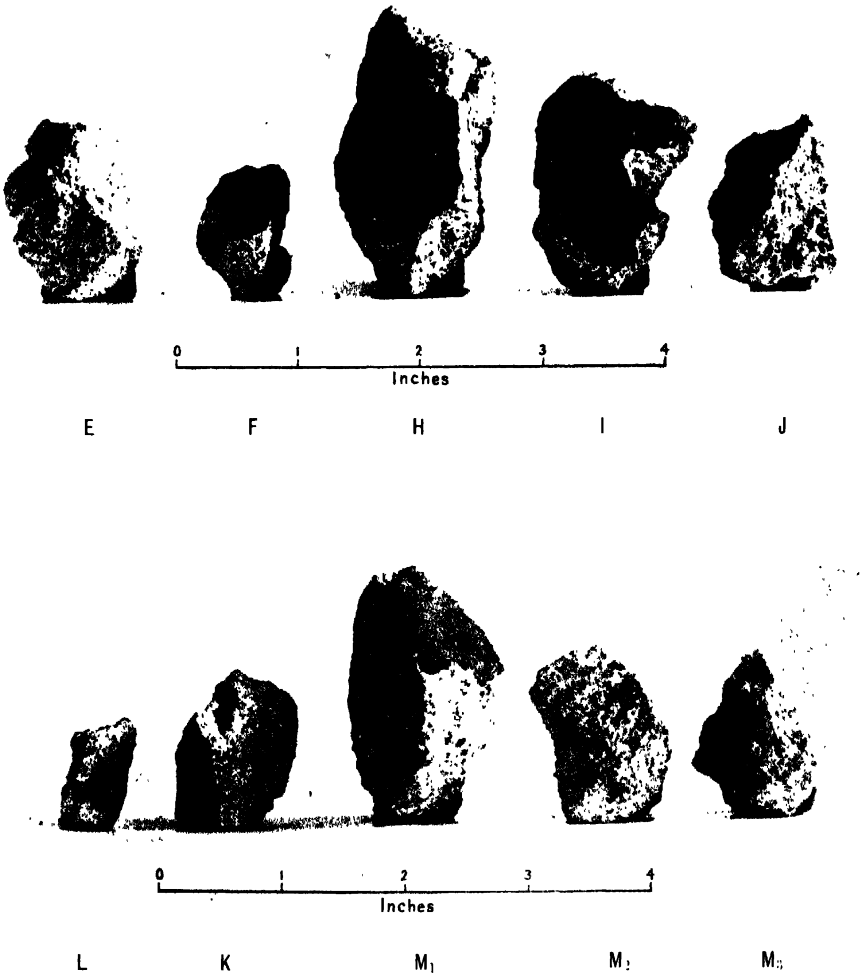
B C D

P. L. Dutt, Photos

G. S. I. Calcutta.

A, B, C, D. FRAGMENTS OF THE RANGALA METEORITE

Records, Vol. 74, Pl. 16.



FRAGMENTS OF THE RANGALA METEORITE

Dutt, Photos *G. S. I., Calcutta.*

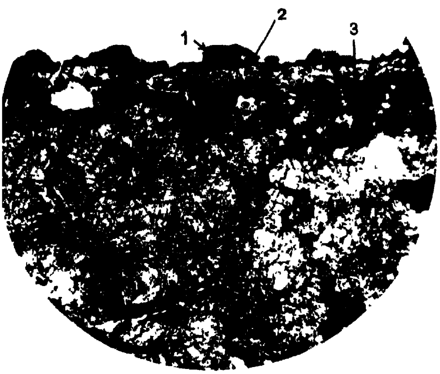


FIG. 1. THIN SECTION, SHOWING THREE ZONES IN THE CRUST. ZONE 1 - SLAG SELVAGE, ZONE 2 — OUTER ZONE OF CRUST, ZONE 3 — INNER ZONE OF CRUST. (× 36.)

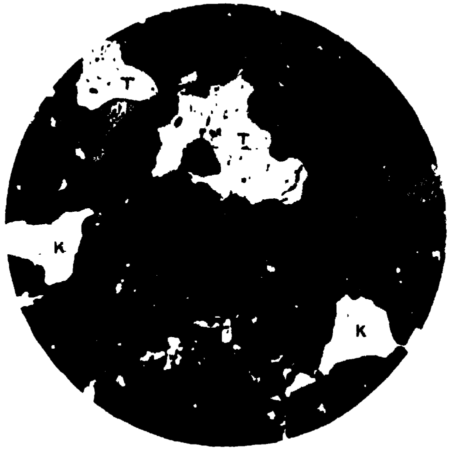


FIG. 2. TROILITE (T), KAMACITE (K) AND CHROMITE (M) IN THE SILICATES. (× 50.)

A. Dunn, Photos.

G. S. I., Calcutta.

FIG. 3. INTERGROWTH OF KAMACITE (ETCHED DARK GREY) AND TAENITE (WHITE). NOTE ALSO TROILITE (T) AND COPPER (C). ETCHED. (× 720.)

FIG. 4. KAMACITE (K) SURROUNDED BY A THIN SHELL OF TAENITE (N). TROILITE (T). ETCHED. (× 100.)

FIG 1. COARSE VEINS OF KAMACITE (K) AND CLEAR TROILITE (T) IN THE SILICATES. TAENITE (N). (× 50).

FIG. 2. VEINLET OF TROILITE (T) IN THE KAMACITE VEIN. (× 50).

Dunn, Photos.

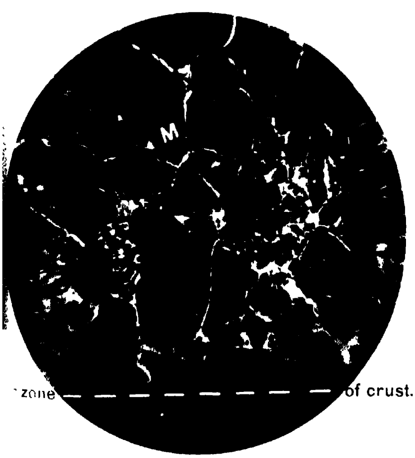
FIG. 3. STRAINED CENTRE TO THE KAMACITE VEIN (K). TAENITE (N) TO ONE SIDE. ETCHED. (× 50).

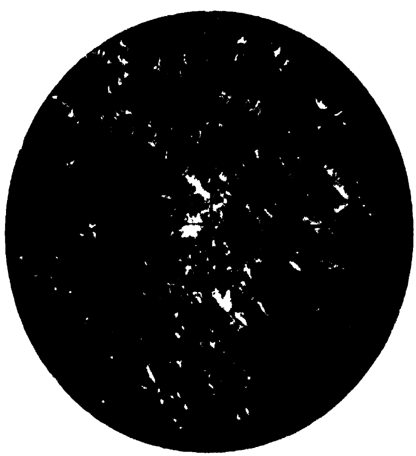
G. S. I., Calcutta.

FIG. 4. EX-SOLUTION IRON (WHITE) IN TROILITE (GREY). NOTE BRANCHING VEINLETS OF TROILITE AND IRON. (× 720).

FIG 1. EX-SOLUTION IRON ON ONE SIDE OF TROILITE, THE OTHER SIDE CLEAR. (× 720.)

FIG. 2. TROILITE AROUND EDGE OF IRON, WITH ALSO VEINLETS OF IRON AND TROILITE. (× 720.)





Dunn, Photos.

G. S. I., Calcutta.

FIG 3. VEINLETS OF IRON AND TROILITE IN CHROMITE (M) AND SILICATES IN THE CRUST. NOTE THAT THE VEINLETS STOP BEFORE THE OUTER EDGE OF THE CRUST IS REACHED. (× 450.)

FIG. 4. SKELETON ? HEMATITE CRYSTALS IN THE SLAG SELVAGE. (× 720)

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA

Part 3] **1939** **[November**

REVIEW OF THE MINERAL INDUSTRY OF INDIA AND BURMA DURING 1938. BY CYRIL S. FOX, D.Sc., F.G.S., M.I.MIN.E., F.R.A.S.B., F.N.I., *Director, Geological Survey of India.*

CONTENTS.

1. INTRODUCTION.

The total value of the ores, minerals and metals produced in India, as distinct from Burma, during the year 1938 has been estimated at no less than Rs. 34,13,93,365 or about £25,477,116 (with the £ equal to Rs. 13·4) as against Rs. 30,49,43,161 or £22,928,057 (with the £ equal to Rs. 13·3) in 1937. This represents an increase of nearly 12·0 per cent. and is largely due to the record production of coal in India, 28,342,906 tons valued at Rs. 10,64,23,835 or £7,942,077, which in itself exceeds the total value of the ores, minerals and metals produced in Burma in 1938.

The total value of the ores, minerals and metals produced in Burma during the year 1938 has been computed to be Rs. 9,93,85,065 or £7,416,793 (with the £ equal to Rs. 13·4) as against Rs. 12,33,96,985

or £9,277,966 (with the £ equal to Rs. 13·3) in 1937. This represents a decrease of over 18·7 per cent. and is largely ascribed to the sharp fall in metal prices in Europe in 1938 as compared with the attractive prices of 1937.

Details of the values of the various ores, minerals and metals, produced in India and Burma during 1937 and 1938, are shown in Tables 1 and 2, and the prices of the principal metals, ores and oils in the United Kingdom are shown in Table 3.

TABLE 1.—*Total value of Minerals, Ores and Metals for which returns of the production in* **India** *are available for the years 1937 and 1938.*

Minerals, Ores and Metals.	1937 (Revised).		1938.		Variation per cent. (on rupee basis).
	Rupees.	£(Rs. 13·3).	Rupees.	£(Rs. 13·4).	
1. Coal	7,81,02,439	5,872,364	10,61,23,835	7,942,077	+36·2
2. Steel*	6,68,63,554	5,027,334	6,96,52,932	5,197,980	+4·2
3. Manganese Ore (*a*)	4,29,53,068	3,229,554	3,92,94,763	2,932,445	—8·5
4. Iron (Pig iron) (*b*)	2,82,78,201	2,126,180	3,44,16,000	2,568,358	+21·7
5. Gold	3,03,95,871	2,285,404	3,04,75,397	2,274,283	+0·3
6. Petroleum	1,37,06,864	1,030,591	1,65,43,142	1,234,563	+20·7
7. Mica (*b*)	1,43,60,030	1,079,702	1,13,25,346	845,175	—21·1
8. Building materials	97,07,817	(*c*)729,911	1,12,65,392	840,701	+16·2
9. Salt	81,47,365	612,584	95,18,383	710,327	+16·8
10. Copper	61,67,490	463,721	44,02,580	328,551	—28·6
11. Ferro-manganese*	10,69,453	80,410	24,63,590	183,850	+130·3
12. Ilmenite	11,26,329	84,686	15,46,436	115,406	+37·3
13. Saltpetre (*b*)	11,17,844	84,048	11,68,440	87,197	+4·5
14. Kyanite, etc.	7,08,623	53,280	7,46,514	55,710	+5·3
15. Chromite	8,35,589	62,826	6,82,502	50,933	—22·4
16. Clays	3,25,578	(*c*)24,480	3,76,270	28,080	+15·5
17. Monazite	1,40,365	10,554	2,33,700	17,440	+66·4
18. Gypsum	1,18,543	8,913	1,71,903	12,829	+45·1
19. Steatite	1,55,221	11,671	1,68,580	12,581	+8·6
20. Magnesite	1,63,938	12,326	1,60,593	11,984	—2·0
21. Fuller's earth	75,017	5,640	78,958	5,892	+5·2
22. Diamonds	54,979	4,134	68,813	5,135	+25·1
23. Zircon	39,036	2,935	40,737	3,040	+4·3
24. Silver	32,343	2,432	29,877	2,230	—7·6
25. Barytes	1,49,200	11,223	29,312	2,187	—80·3
26. Ochres	28,193	(*c*)2,120	28,865	2,154	+2·3
27. Bauxite	61,839	4,649	25,540	1,906	—59·1
28. Graphite	16,302	1,226	20,691	1,544	+26·9
29. Iron-ore (*aguria*)	1,062	80	12,690	947	+1,093·9
30. Tungsten-ore	24,500	1,842	9,600	716	—60·8
31. Asbestos	6,022	453	4,482	334	—25·5
32. Felspar	3,390	255	4,335	324	+27·8
33. Beryl	1,969	148	1,597	119	—18·8
34. Garnet sand	1,650	124	600	45	—63·7
35. Bentonite	900	68	330	25	—63·3
36. Corundum	..	..	250	19	+100·0
37. Sapphire	550	41	150	11	—72·7
38. Apatite	1,660	125	119	9	—92·8
39. Copper-ore	..	..	101	8	..
40. Aquamarine	..	..	14	1	+100·0
41. Tantalite	301	23	..	..	—100·0
42. Antimony-ore	..	..	..	..	..
TOTAL	**30,49,43,161**	**22,928,057**	**34,13,93,365**	**25,477,116**	**+11·9**

(*a*) Export f.o.b. values. (*b*) Export values (p. 316). (*c*) Revised. * Underestimated (p. 318).

The average value of the Indian Rupee in 1938 was 1*s.* 5·94r*d.*, which is equivalent to Rs. 13·378 to the £, but for ease of calculation the figure Rs. 13·4 equal to the £ has been adopted. Similaly in 1937 when the average value of the Rupee was 1*s.* 6·093*d.*, which is equivalent to Rs. 13·27 to the £, the figure adopted was Rs. 13·3 to the £.

TABLE 2.—*Total value of Minerals produced in* **Burma** *for which figures of production are available for the years 1937 and 1938.*

—	1937.		1938.		Variation per cent. (on rupee basis).
	Rupees.	£(Rs. 13·3).	Rupees.	£(Rs. 13·4).	
Petroleum (*a*)	5,95,06,155	4,474,147	5,04,75,254	3,766,810	—15·2
Lead	2,39,62,860	1,801,719	1,64,40,630	1,226,913	—31·3
Tungsten concentrates	80,22,748	603,214	81,39,488	607,424	+1·4
Tin concentrates	1,09,59,215	824,001	78,93,160	589,042	· 27·9
Silver	73,60,998	553,458	68,83,184	513,670	—6·4
Zinc concentrates	54,40,421	409,054	30,77,959	229,698	—38·9
Building materials	25,87,512	194,550	24,54,636	183,182	—14·9
Copper matte	24,18,465	181,839	16,11,091	120,230	—33·4
Nickel speiss	13,91,049	104,590	11,06,323	82,561	—20·4
Salt (*a*)	8,24,953	62,026	5,94,014	44,329	—27·9
Antimonial lead	4,20,976	31,652	2,96,090	22,096	—29·6
Ruby and sapphire	94,025	7,069	1,47,476	11,006	+56·8
Gold	84,234	6,333	1,05,114	7,846	+24·8
Iron-ore (*a*)	1,01,704	7,647	72,200	5,388	—29·0
Jadeite	1,73,304	13,030	57,891	4,320	—66·5
Clays	18,175	1,367	19,702	1,477	+8·8
Soapsand	21,307	1,602	10,733	801	—49·6
Amber	8,880	668	..	..	..
TOTAL	**12,33,96,985**	**9,277,966**	**9,93,85,065**	**7,416,793**	**—18·7**

(*a*) Estimated.

Revised Total Value.

If the total value of the ores, minerals and metals produced in India in 1937, as given in Table 1, is compared with the corresponding figure, also for 1937, published in "The Mineral Production of India and Burma during 1937" (*Records, Geol. Surv. India*, Vol. 73, Part 3, page 307, 1938), a great difference will be noted. The total value of the ores, minerals and metals produced in India in 1937 according to data previously published is given as £15,942,213 or Rs. 21,20,31,432 as against £22,928,0[illegible]8 or Rs. 30,49,43,161 as revised in this review. The enormous increase, 43·8 per cent. nearly, in the total value, as re-calculated, for the same year—no less than Rs. 9,05,24,109 or £6,806,345—has been the result of estimating the value of the Indian ores, minerals and metals in exactly the same way as has been long used for estimating the value of the ores. minerals and metals produced in Burma.

As is well known the lead-zinc-copper ores of Bawdwin, Northern Shan States, are smelted at Namtu and yield antimonial-lead, copper-matte, gold, lead, nickel-speiss, silver and zinc concentrates. The estimated value of the Bawdwin ore produced in 1937 was £964,227, whereas the total value of the various metallic products obtained from them in Burma was computed at no less than £3,082,312. In compiling the total value of the ores, minerals and metals produced in Burma no mention of the value of the lead-zinc-copper ores is made while the several metallic products are separately recorded. The result has been the total value of the ores, minerals and metals produced in Burma represents the total value of raw minerals, concentrates and products of smelting ores. In 1938 when the value of the Bawdwin ore output was only £471,201 the metallic products obtained in Burma from those ores were valued at £2,195,168.

It is also well known that almost the whole of the iron-ore production of India is smelted for the production of pig-iron and steel, and with some manganese-ore in preparing ferro-manganese, in India. In 1937 the production of iron-ore was valued at £344,840, whereas the output of pig-iron and steel, deducting pig-iron used in steel-making, was valued at £2,131,111 and £5,027,334, respectively. Heretofore, the total value of the ores, minerals and metals produced in India have included the value of the iron-ore and omitted the metallic products obtained from it, which is not uniform with the method used in Burma. Following the mode of estimating as used for Burma the difference between the value of the iron-ore and that of the pig-iron and steel obtained from it in 1937 is no less than £6,813,605. It may be mentioned that the pig-iron is valued at export prices and the steel at only £7-10 per ton—both underestimates for the whole.

Mineral Groups.

In the first review of the mineral production of India, in 1894, Sir George Watt classified the minerals in two Groups I.—Those for which approximately trustworthy returns are available, and II.—Those regarding which definitely recurring particulars cannot be procured. Sir George Watt's *Group* I of 1894 contained only *four* minerals—Coal, Iron-ore, Petroleum and Salt. Ten years later when Sir Thomas Holland prepared the first "Review of the Mineral Production of India", which was published in the *Records of the Geological Survey of India* (Vol. XXXII, page 3) in 1905, he adopted the same grouping, but

was able to include *thirteen* minerals in Group I.—Coal, Gold, Graphite, Iron-ore Jadeite, Magnesite, Manganese-ore, Mica, Petroleum, Rubies, Salt, Saltpetre and *Tin.* Although Sir Thomas Holland wrote "Tin" he clearly only dealt with "Tin-ore" in his Table I (*Supra*, page 7), when estimating the total values of the mineral production of India in 1898-1903, as seen in his Table 51 (*Supra*, page 91).

In successive reviews of the mineral production of India the number of minerals placed in *Group* I has steadily increased. Sir Lewis Fermor, in the Quinquennial Review of the Mineral production of India during the years 1929-33 (*Records Geol. Surv. India*, Vol. LXX, pages 7-8, 1935) included *twenty-six*--double the number in 1905. In the present review of the Mineral Industry of India, Table I, 42 minerals, metals and ores could also be placed in Group I if so desired. In the list given by Sir Lewis Fermor the terms "Iorn" and "Manganese" replace the names Iron-ore and Manganese-ore, respectively, although it is the ores he deals with chiefly. Similarly in the case of Burma he refers to Lead, Nickel, Tin, Tungsten and Zinc in his list of minerals in Group I in spite of the fact that none of these metals are found native in that country.

In view of the large number of metallic products which are now included in Group I, and the fact that the relative values of the mineral returns are not greatly different nowadays it seems unnecessary to continue to classify the various ores, minerals and metallic products which are discussed in these reviews. If a particular case of irregularity were desired mica is a good example because it has been frequently pointed out that the production figures are incomplete and that a more accurate idea of the size of the industry is to be obtained from export figures! (*Records Geol. Surv. India*, Vol. 73, Part 3, page 343, 1938). Considering the whole question from the point of view of the mineral industries of India and Burma it seems far simpler and logical in every way to discuss the various ores, minerals and metals produced in India and Burma in "Alphabetical Order".

Mineral Industry.

"The Mineral Industry" which is published annually by the McGraw-Hill Book Company of New York, deals fully with all the ores, minerals and metals obtained therefrom in most countries in the world, including India and Burma for their relatively more important minerals and ores and metallic products. In view of what has already been

discussed in the previous paragraphs regarding the inclusion of such substances as antimonial-lead, copper-matte and nickel-speiss under the designation of minerals it seems necessary to re-consider the title "Mineral Production" so far adopted for these reviews. Although they deal with the ore, mineral and metal production of India and Burma the brief name Mineral Production seems inappropriate in view of the fact that the metallic products cannot be considered as natural minerals. It is proposed, therefore, to follow the American style and use the term "Mineral Industry" as being both brief and accurate as well as comprehensive, and thus the title "The Mineral Industry of India and Burma during 1938" appears to be suitable for this review.

Progress of Production.

Attention has already been drawn to the record production of Coal in India in 1938 when the value of the output increased over 36 per cent. above that of 1937. Among other Indian minerals, ores and metals produced in 1938 and with regard to the rise or fall in the total value of their output, compared with 1937, details are seen in Table 1. Among these steel has improved slightly, pig-iron is also better, but manganese-ore has fallen with the fall in its market price. The gold output is steady, petroleum has improved and have building materials and salt, but mica has fallen very appreciably and so has copper.

Ferro-manganese has more than doubled in total value while ilmenite is still soaring and India is a leading producer of this mineral. Chromite has fallen in total value while monazite, gypsum and steatite have improved. Diamonds, graphite and felspar have improved as against barytes, bauxite, asbestos and tungsten-ore which have fallen. In the case of bauxite the fall in total value is entirely due to the market value and not to quantity. The total values of apatite, beryl, garnet and sapphire production have all fallen off greatly. The exploration of Indian tungsten-ore is of considerable interest as is also the occurrence of antimony-ore (zinckenite) in Chitral.

So far as the total value of the ore, mineral and metal production of Burma is concerned there has been an over-all fall which is ascribed to the depreciation of metal prices in the United Kingdom which is clearly evident in the case of the metallic products from the Bawdwin ores; lead fell over 31 per cent., zinc concentrates nearly 39 per cent., copper-matte ove 33 per cent., nickel-speiss

20 per cent. and antimonial lead 30 per cent. in total value. In the case of tin-ore concentrates the fall in total value was about 28 per cent. The tungsten-ore (wolfram) concentrates remained steady in total value in spite of the fall in prices. As though the tale of woe were not complete it must be mentioned that petroleum, the premier mineral industry of Burma showed a decline in total value of production of nearly 15 per cent. Salt fell nearly 28 per cent., iron-ore 29 per cent., jadeite (jadestone) nearly 67 per cent. and soapsand 50 per cent. In such circumstances gold and precious stones (rubies and sapphires) have cheered the situation slightly by showing advancement of nearly 25 per cent. and 57 per cent. in total value on the figures for the previous year.

TABLE 3.—*Average Prices in the United Kingdom of Principal Metals, Ores and Oils during the years 1937 and 1938.*

——		1937.	1938.
Metals—			
Copper, standard, per ton	£	54·50	40·33
Lead, pig, soft, foreign, per ton	£	23·30	15·33
Spelter, ordinary, per ton	£	22·34	14·08
Tin, standard, per ton	£	242·33	189·58
Pig iron, Cleveland No. 3, per ton	£	4·60	5·58
Steel rails, per ton	£	9·55	10·08
Ferro-manganese, per ton	£	16·60	18·50
Gold, fine, per ounce	sh.	140·666	142·522
Silver, standard, per ounce	d.	20·071	19·526
Ores—			
Chromite, 48-57 per cent., per ton	£	4·425	4·70
Manganese-ore, first grade, per unit	d.	22·50	19·70
Wolfram, per unit	sh.	69·833	58·41
Oils—			
Petrol, per gallon	d.	10·0	9·3
Kerosene, per gallon	d.	8·50	8·28

Mineral Concessions.

The number of mineral concessions granted in India in 1938 was 468 prospecting licences, 137 mining leases and 36 quarry leases, that is, 641 mineral concessions in all. In the previous year, 1937, the figures were 291

prospecting licences, 57 mining leases and 25 quarry leases, or 373 total. In Burma the number of mineral concessions granted in 1938 was 469 prospecting licences and 64 mining leases making a total of 533, as against 271 prospecting licences and 46 mining leases, or 317 in all, in 1937. The figures for 1938 surpass the record for 1925 when the total for India and Burma was 859 and shows how interest in mining is progressing in India and Burma.

British India and Indian States.

Since the figures of mineral production published in these Reviews are in many cases greater than those published in the Annual Returns of the Chief Inspector of Mines, it is desirable to explain that the figures published by the Chief Inspector of Mines are confined to mines and workings that come under the Mines Act, which relates only to British India; whereas the figures published in these Reviews include the production of both Act and non-Act workings in British India, and also the production of the Indian States.

Persons employed in mines.

The average number of persons employed daily during 1938 in and about Indian mines relating to the minerals mentioned in Table 4, was 413,458 as against 373,129 in the previous year. Details of the various minerals for the exploitation of which this labour was engaged are shown in Table 4. The figures for Burma are not available. It will be seen that the most important mineral industries (for which reliable labour returns are available) which provide employment in India are, in order, coal, salt, manganese-ore, mica, gold and iron-ore—all near or above 20,000 persons. Strictly speaking the iron and steel industry should be included and it is proposed to obtain data in this connection for the next review.

Consumption of minerals in India.

With regard to Table 5 which endeavours to give an idea of the consumption of ores, minerals and metals in India it is necessary to draw attention to a paper on "Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India" which was published in the Records of the Geological Survey of India (Volume LXVI, Part 4, page 405) in 1933 and deals with the information available for 1913, 1917, 1920 and 1926 and up to 1931. It also includes particulars on the smelting and refining facilities in this country as at the end of July, 1932.

Sources of Information.

For the provision of the data compiled in these Reviews we are indebted to the Chief Inspector of Mines and the Local Governments with regard to British India; to the Indian Durbars and Political Agents in the case of Indian States; and to the Managements of the mining companies. In the case of Burma, which was separated from India on the 1st April, 1937, the data are forwarded by the Burma Government but the information is kept separate from those of India as seen in Tables 1 and 2 and elsewhere in this Review of the Mineral Industry of India and Burma.

TABLE 4.—*Average number of persons employed daily in 1936, 1937 and 1938 in the production of minerals from mines in India for which reliable returns of labour statistics are available. (Figures for Burma not included.)*

—	1936.	1937.	1938.
Chromite	2,207	2,689	1,958
Coal	181,687	194,705	226,887
Copper-ore	2,878	3,216	2,743
Diamonds	1,246	983	1,005
Gold	23,103	24,119	24,200
Iron-ore	21,118	20,043	19,577
Magnesite	1,163	1,674	1,686
Manganese-ore	20,796	30,208	34,080
Mica	25,151	29,421	31,066
Monazite, ilmenite, zircon	3,513	3,430	4,856
Petroleum	4,343	6,866	7,655
Salt	55,561	55,625	57,665
Tungsten concentrates	..	150	80
TOTAL	342,766	373,129	413,458

TABLE 5.—*Consumption in India during the year 1938.*

Ores, minerals and metals.	Unit.	Production.	Retained imports into India.	Exports of domestic production.	Total available for consumption.
Aluminium, metal unwrought	Cwts.	..	51	..	51
Aluminium ore-Bauxite	Tons	14,768	..	(a)	..
Arsenic and oxides	Cwts.	(f)	4,693	..	4,693
Asbestos	Tons	89	(e)	..	..
Barytes	Tons	8,075	375	..	8,450
Bentonite	Tons	33	..	..	33
Beryl	Tons	17	..	(a)	..
Borates, borax	Cwts.	(b)	26,411	814	26,411
Brass	Tons	9,363	15,451	509	24,305
Clays, other	Tons	294,754	..	..	294,754
China clay	Tons	26,106	25,713	..	51,819
Chrome-ore, chromite	Tons	44,149	..	(d)24,452	19,697
Coal and Coke	Tons	28,342,906	46,740	1,343,033	27,046,613
Coal tar and pitch	Tons	64,423	2,501	..	66,924
Sulphate of ammonia	Tons	14,616	72,554	1,313	85,857
Copper, metal unwrought	Tons	5,330	2,513	..	7,843
Diamonds	Carats.	1,729	(e)	..	1,729
Ferro-manganese	Tons	18,385	..	..	18,385
Ferro alloys	Tons	..	4,203	..	4,203
Felspar	Tons	691	..	..	691
Fuller's earth	Tons	8,059	..	..	8,059
Garnet sand	Tons	120	..	(a)	..
Gold	Fine ounces.	321,138	87,855	(f)1,649,580	..
Graphite	Tons	458	425	..	883
Gypsum	Tons	69,823	..	..	69,823
Ilmenite	Tons	252,220	..	225,592	26,628
Iron ore	Tons	2,743,675	..	..	..
Pig	Tons	1,539,889	2,412	525,254	1,017,047
Steel	Tons	693,064	56,180	3,357	745,887
Other	Tons	(g)	200,340	61,245	139,095
Magnesite	Tons	25,611	..	6,382	19,229
Manganese-ore	Tons	967,929	..	(h)648,740	319,189
Mica	Cwts.	123,169	..	(i)175,109	..
Monazite	Tons	5,221	..	4,136	1,085
Ochre	Tons	5,616	..	..	5,616
Petroleum, crude	Gallons	87,082,371	..	..	..
Natural-gas-gasolene	Gallons	496,163	..	..	..
Petrol, benzene, kerosene, fuel oil, batching and lubricating oil, etc.	Gallons	66,532,630	447,104,402	334	513,636,698

(a) Known to be exported but export figures are not available.
(b) Known to be produced, but production figures are not available.
(c) Complete figures for quantity are not available ; value Rs. 20,36,585.
(d) Includes 6,238 tons produced in India but exported from Mormugao in Portuguese India.
(e) Quantity unknown. Value of diamonds imported in 1938 amounted to Rs. 1,18,14,990.
(f) Total exports, largely imported in previous years.
(g) Not available.
(h) Includes 130,398 tons produced in British India but exported from Mormugao in Portuguese India.
(i) Includes splittings.

TABLE 5.—*Consumption in India during the year 1938*—contd.

Ores, minerals and metals.	Unit.	Production.	Retained imports into India.	Exports of domestic production.	Total available for consumption.
Phosphates	Tons	23	12,281	..	12,304
Potash saltpetre	Cwts.	(a)154,824	..	148,824	6,000
Potash chemicals, etc.	Cwts.	..	117,826	..	117,826
Quicksilver	Lbs.	..	155,309	..	155,309
Refractory materials	Tons	(b)44,076	(c)	..	..
Salt	Tons	1,539,663	331,955	..	1,871,618
Silver	Ounces	22,295	17,472,926	8,817,822	8,677,399
Steatite	Tons	17,990	.	..	17,990
Sulphur	Cwts.	..	459,282	..	459,282
Tungsten-ore	Tons	10	..	8	2
Zircon	Tons	1,450	..	(d)1,727	..

(a) 148,824 cwts. exported and 6,000 cwts. consumed in the tea gardens in India.
(b) Includes 28,385 tons of kyanite.
(c) Known to be exported, but export figures are not available.
(d) 277 tons from stock of previous year.

TABLE 6.—*Quantity and Value in Rupees of all Minerals and Mineral Oils* **exported** *from Burma during the year ended the 31st December 1938.*

Articles.	Unit.	TO FOREIGN COUNTRIES.		IN INDIA.		TOTAL.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Precious Minerals and Metals—							
Jadestone . .	Cwt.	204	18,808	..	..	204	18,808
Silver-bar . .	Std. oz.	2,080,849	22,79,730	4,156,237	44,52,601	6,237,086	67,32,331
Other minerals and metals—							
Copper matte . .	Cwt.	114,995	13,73,591	..	..	114,995	13,73,591
Pig-lead . . .	,,	1,532,174	2,36,65,600	119,771	18,12,608	1,651,945	2,54,78,208
Lead, other sorts .	,,	25,053	4,02,618	1,418	21,090	26,471	4,23,708
Tin-ore . . .	Ton	2,843	47,26,658	..	..	2,843	47,26,658
Tin-blocks . . .	Cwt.	25	2,186	4,968	6,65,735	4,993	6,67,921
Tungsten-ore . .	Ton	10,431	2,20,85,747	..	..	10,431	2,02,85,747
Zinc concentrates .	Cwt.	1,202,996	29,81,645	20	310	1,203,016	29,31,955
Chalk and lime .	,,	..	..	259	2,177	259	2,177
Mineral oil of all kinds	Gal.	84,351	83,204	210,102,761	11,13,19,766	210,187,112	11,14,02,970
Stone and marble .	Ton	(10 cwt.)	314	(a)	185	..	499
Antimony-ore . .	,,	181	18,567	45	9,000	226	27,567
TOTAL .	..	..	**5,57,88,369**	..	**11,82,83,387**	..	**17,40,71,756**

(a) Recorded separately from April 1938.
(b) There were 4,622 tons of mixed tin and wolfram concentrates valued at Rs. 92,44,000 exported from Mawchi Mines, Ltd.

TABLE 7.—*Quantity and Value in Rupees of all Minerals and Mineral Oils* **imported** *into Burma during the year ended the 31st December 1938.*

Articles.	Unit.	From Foreign Countries.		From India.						Grand Total.	
				Indian Merchandise.		Foreign Merchandise.		Total.			
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Precious minerals—											
Diamonds	Value	..	21,83,797	..	..	..	..	..	..	..	12,83,797
Pearls	"	..	3,754	..	..	..	..	..	..	..	3,754
Other precious stones	"	..	2,18,367	..	..	..	..	..	..	..	2,18,367
Silver	Std. oz.	16,322	16,268	..	..	..	..	..	..	16,322	19,268
Other minerals—											
Chalk and lime (excluding French Chalk).	Cwt.	5,167	14,676	564	3,315	26	77	590	3,392	5,757	18,068
China Clay	"	7	514	22	85	..	..	22	85	29	599
Clay	"	5,816	22,194	8,707	19,491	646	1,858	9,353	21,349	15,169	43,543
Coal	Ton	16,431	2,90,645	371,374	59,06,022	12,384	98,477	385,758	60,04,499	400,239	62,95,144
Copper ingots	Cwt.	70	2,461	205	9,815	16	769	221	10,584	291	13,045
Iron ore	Ton	(b)	12	..	..	..	..	..	..	..	12
Iron, pig	"	27	2,962	270	22,200	..	..	270	22,200	297	25,162
Tin blocks	Cwt.	641	1,06,076	103	1,500	8	1,220	111	2,720	52	1,08,796
Lead ingots (unwrought).	"	23	558	8	115	1	13	9	128	327	686
Lead, pig	"	..	..	..	..	4	561	41	561	41	561
Zinc block	"	44	1,245	..	..	4	624	24	624	68	1,869
(a) Antimony-ore	"	..	..	..	..	..	..	..	..	..	..
Ore (unenumerated)	Ton	1,594	55,564	298	13,774	201	3,880	499	17,654	2,093	73,218
Mica blocks	Cwt.	(b)	235	..	..	..	..	..	..	..	235
(a) Red ochre	"	..	..	..	..	..	..	..	..	..	..
Fuel oil	Gal.	28,831,302	43,23,277	21,452	8,357	7,849	1,595	29,301	9,952	28,860,603	43,33,229
Kerosene oil in tins	"	502,000	2,75,218	56,802	41,207	32	19	56,834	41,226	558,834	3,16,444
Lubricating oil	"	980,314	13,36,085	16,725	21,581	15,930	33,104	32,655	54,685	1,012,969	13,90,770
Petroleum, dangerous	"	12,165	19,334	11,096	23,748	8,603	16,429	19,699	40,177	31,864	59,511
Paint oil	"	3,086	19,163	..	..	..	..	..	..	3,086	19,163
Oil—other kinds	"	62,626	37,321	74,478	40,614	4,693	3,945	79,171	44,559	141,797	81,880
Stone and marble	Cwt.	207	12,364	29	2,876	1	25	30	2,901	237	15,265
TOTAL	..	..	80,45,090	..	61,14,700	..	1,62,596	..	62,77,296	..	1,43,22,386

(a) Figures are not ascertainable.
(b) Weight not recorded.

2. ORES, MINERALS, ETC., PRODUCED IN INDIA AND BURMA.

Amber.

The production of amber in the Myitkyina district, Burma, was 3·7 cwts. valued at Rs. 152 (£12) in 1934, 18·6 cwts. valued at Rs. 2,100 (£158) in 1935, 32·4 cwts. valued at Rs. 5,440 (£409) in 1936, and 38·7 cwts. valued at Rs. 8,880 (£668) in 1937. There was no recorded output in 1938.

Antimony.

The mineral zinckenite has been found in Chitral at Shoga where 31 tons have been extracted in the last two years. No valuation has been communicated on this antimony-lead sulphide (*see* Zinckenite).

Burma.

The production of antimonial lead obtained as a bye-product in the lead refinery at the Namtu smelter of the Burma Corporation Limited, increased from 1,150 tons, valued at Rs. 4,20,976 (£31,652) in 1937 to 1,200 tons valued at Rs. 2,96,090 (£22,096). This product contains 81·76 per cent. of lead, 17·59 per cent. of antimony, 0·22 per cent. of copper and 2·93 ozs. of silver to the ton, and is exported for further treatment. An output of 181 tons of antimony-ore was reported in 1938, but the value and district of origin have not been reported by the Burma Government.

Apatite.

The production of apatite in the Singhbhum district, Bihar, was 22 tons valued at Rs. 3,300 (£244) in 1930, but *nil* in 1931 to 1937. The output of apatite in the Trichinopoly district, Madras, rose from 37 tons valued at Rs. 372 (£28) in 1933 to 59 tons valued at Rs. 885 (£67) in 1934, to 102 tons valued at Rs. 1,532 (£115) in 1935, to 128 tons valued at Rs. 1,315 (£99) in 1936, and to 166 tons valued at Rs. 1,660 (£125) in 1937, but fell to 23 tons valued at Rs. 119 (£9) in 1938.

Aquamarine.

The output of aquamarine from the deposits of Daso in Ladakh in Kashmir rose from 686 tolas (39,000 carats) valued at Rs. 686 (£52) in 1933 to 1,221 tolas (69,471 carats) in 1934. The value of

the 1934 production was not reported and there was no production during 1935 and 1936. In 1937 the output was 110 tolas, and 29 tolas valued at Rs. 14 (£1) in 1938.

Asbestos.

In 1935 the production amounted to 62·7 tons, composed of 2·7 tons valued at Rs. 1,267 (£95) from the Cuddapah district, and 60 tons valued at Rs. 3,300 (£248) from Seraikela State in the Eastern States Agency. In 1936 the production was 56·5 tons valued at Rs. 3,107 (£234) from Seraikela State, and in 1937, 100 tons valued at Rs. 6,000 (£451) from Seraikela State and 9 cwts. valued at Rs. 22 (£2) from Ajmer-Merwara. In 1938 the output was as follows :—

	Tons.	Rs.	£
Eastern States Agency Seraikela State	63·0	3,810	284
Mysore State	23·0	575	43
Rajputana—Ajmer-Merwara . .	2·7	97	7
	88·7	4,482	334

Barytes.

The production of barytes in India rose from 3,813 tons valued at Rs. 35,263 (£2,651) in 1934 to 5,493 tons valued at Rs. 34,954 (£2,628) in 1935, but fell slightly to 5,114 tons valued at Rs. 16,049 (£1,206) in 1936. In 1937 the production more than tripled, to 15,689 tons valued at Rs. 1,49,260 (£11,223). In 1938 the output was half that of 1937 as seen in Table 8. The chief producing district was Cuddapah in the Madras Presidency.

TABLE 8.—*Quantity and value of Barytes produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value (Rs. 13·3).		Quantity.	Value (Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Cuddapah	15,405	1,46,720	11,032	7,732	26,252	1,959
Kurnool	130	1,150	86	200	1,800	134
Rajputana—						
Alwar State . . .	154	1,390	105	143	1,260	94
Jaipur State . . .	..	..	..	..	..	..
TOTAL .	15,689	*1,49,260*	*11,223*	8,075	*29,312*	*2,187*

Bauxite.

In 1934 the output was only 18 tons valued at Rs. 90 (£7), from the Jubbulpore district, but rose in 1935 to 7,635 tons valued at Rs. 15,270 (£1,148) falling again to 3,644 tons valued at Rs. 7,288 (£548) in 1936. In 1937 there was a large increase, to 9,588 tons valued at Rs. 16,319 (£1,227), from Jubbulpore district, and Kaira district recorded a production of 5,592 tons, valued at Rs. 45,520 (£3,422). In 1938 the Jubbulpore district produced 14,768 tons valued at Rs. 25,540 (£1,906). There was no output from the Kaira district. Returns of bauxite from Bihar for several years have so far not been recorded.

Bentonite.

In Jodhpur State, Rajputana, there was in 1937 a production of 90 tons of bentonite valued at Rs. 900 (£68), and in Mirpur district, Kashmir, 56 tons, valued at Rs. 1,350 (£102), in 1936. In 1938 Jodhpur State yielded 33 tons valued at Rs. 330 (£25).

Beryl.

In 1932 there was a production in Ajmer-Merwara of 281 tons of beryl valued at Rs. 5,281 (£397) which rose to 324 tons valued at Rs. 7,261 (£546) in 1933, falling to 55 tons valued at Rs. 1,650 (£124) in 1934, rising in 1935 to 139 tons valued at Rs. 8,519 (£641), but falling again to 98 tons valued at Rs. 6,184 (£465) in 1936 and to 26·6 tons valued at Rs. 1,969 (£148) in 1937, and further to 17·4 tons valued at Rs. 1,597 (£119) in 1938. This beryl is shipped to Germany and the United States of America for use as beryllium-ore, *i.e.*, for the extraction of the metal. The Indian beryl is of high grade and fetches from £7 to £10 per ton *c.i.f.* in America and Europe, so that it is obviously undervalued in the returns. There appears to be no previous example of the production anywhere in the world of beryl on such a large scale.

Bismuth.

The production of native bismuth from the Tavoy district, Burma, was in 1935, 224 lbs. valued at Rs. 211 (£16) and in 1936, 112 lbs. valued at Rs. 112 (£8). In 1937, 246 lbs. were produced. There was no production in 1938.

TABLE 9.—*Production of Building materials and Road*

—	Granite.		Laterite.		Lime.		Limestone and Kankar.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Assam	6,202	12,752	12,268	13,767	..	..	68,496	79,792
Bengal	73,086	82,871	..	..	..	..	..	..
Bihar	616,995	6,41,500	..	..	..	..	613,138	8,44,147
Bombay	..	..	70,577	5,953	..	..	450	5,400
Central India	..	..	..	..	28,209	1,75,557	93,445	43,304
Central Provinces	22,408	20,093	48	16	..	..	551,078	6,18,274
Delhi	..	..	..	..	..	..	..	..
Eastern States Agency	3,302	726	123	31	..	..	(a) 754,014	17,62,286
Gwalior	..	..	..	..	..	..	88,943	36,545
Kashmir	..	..	1,118	2,653	..	..	735	(b)
Madras	165,089	1,89,185	..	..	..	..	180,757	93,570
Mysore	3,991	23,953	..	..	885	4,481	28,466	94,856
North-West Frontier Province.	..	..	..	..	..	..	..	..
Orissa	..	..	..	..	..	..	10	(b)
Punjab	59,486	71,332	..	..	..	..	300,479	2,19,464
Rajputana	9	47	..	..	..	..	375,600	5,81,332
Sind	..	..	..	..	..	..	..	..
United Provinces	98,001	1,31,565	..	..	..	..	(c)888,453	6,91,535
TOTAL	1,048,569	*11,74,024*	84,134	*22,420*	29,094	*1,80,038*	3,953,973	*50,70,505*
Burma	..	..	..	..	..	..	..	..

(a) Includes 25,911 tons
(b) Not reported.
(c) Includes 875,440 tons
(d) Estimated.
(e) Includes production of

metal in India and Burma during the year 1938.

Marble.		Sandstone.		Slate.		Trap.		Miscellaneous building material and road-metal.		Total Value £ (Rs. 13·4).	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Rs.	£
..	..	18,462	29,990	..	..	..	..	809,752	5,13,874	6,50,175	48,521
..	..	..	..	..	..	..	..	..	..	82,871	6,184
..	..	20,851	13,590	820	11,470	5,420	2,603	44,376	36,089	15,49,408	115,627
..	..	..	..	..	..	384,567	14,30,870	103,241	93,286	15,35,509	114,590
..	..	..	..	..	..	..	..	2,306	6,953	2,25,814	16,852
..	..	..	..	..	..	..	..	59,065	41,357	6,79,740	50,727
..	..	..	..	..	..	..	..	11,178	6,707	6,707	501
..	..	..	..	..	..	..	..	..	..	17,63,043	131,570
..	..	12,528	17,037	..	..	..	..	..	..	58,582	3,999
..	..	84	18	5,328	10,059	..	..	45,273	(*d*)11,120	23,850	1,780
..	..	..	..	..	..	..	..	1,435,763	5,85,280	8,68,035	64,779
..	..	..	..	10	36	..	..	237,213	1,72,909	2,96,325	22,114
..	..	..	..	..	..	..	..	13,190	21,739	21,739	1,622
..	..	59	..	..	..	..	..	5,029	441	441	33
..	..	..	..	7,236	1,54,304	..	..	5,213	1,588	4,46,688	33,335
7,969	37,906	225,674	6,90,289	67	1,005	..	..	178,882	1,40,134	14,50,713	108,262
..	..	..	..	..	..	..	..	30,303	22,372	22,372	1,669
..	..	323	726	63	180	..	..	429,819	7,04,374	15,88,380	118,536
7,969	*37,906*	277,081	*7,51,659*	13,524	*1,77,054*	389,987	*14,33,473*	2,911,203	24,18,313	1,12,65,392	840,701
..	..	..	..	..	..	..	..	(*e*) 2,545,098	24,54,636	24,54,636	183,182

of dolomite.

of Kankar.

granite, laterite, limestone, etc.

Building materials and road-metal.

The total estimated value of building materials and road-metal produced in India and Burma in the year under consideration was Rs. 1,12,65,392 (£840,701) and Rs. 24,54,636 (£183,182) respectively, as against Rs. 97,07,817 (£729,911) and Rs. 25,87,512 (£194,550), respectively, in 1937. Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight.

The production of limestone and *kankar* during the year amounted to nearly 4 million tons, and if weight of material won were the criterion, then limestone would be rated next to coal in order of importance. The increased output of limestone of recent years is partly due to its use as a flux in the iron and steel industry and in the manufacture of cement.

Chromite.

There was a decrease of 29 per cent. in the production of chromite in India, from 62,307 tons valued at Rs. 8,35,589 (£62,826) in 1937 to 44,149 tons valued at Rs. 6,82,502 (£50,933) in 1938. The total exports from India during the year were 24,452 tons made up of 18,214 tons from British India and 6,238 tons from Mormugao in Portuguese India, as compared with 37,085 tons and 13,282 tons, respectively in the previous year. The exports were thus less than half of those of 1937. The value per ton was Rs. 15·5, as against Rs. 13·4 for 1937.

TABLE 10.—*Quantity and value of Chromite produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity. Tons.	Value = (Rs. 13·3) Rs.	£	Quantity. Tons.	Value = (Rs. 13·4). Rs.	£
Baluchistan—						
Quetta-Pishin	45	675	51	303	4,050	309
Zhob	27,164	4,04,540	30,417	21,580	3,21,064	23,960
Bihar—						
Singhbhum	7,678	1,07,258	8,064	5,194	99,028	7,458
Bombay—						
Ratnagiri	500	(*a*) 5,000	376	..	..	..
Eastern States Agency—						
Seraikela	520	5,200	391	94	940	70
Mysore State—						
Hassan	16,148	1,35,572	10,193	7,259	77,905	5,814
Mysore	10,252	1,77,344	13,334	9,710	1,77,715	13,262
TOTAL	62,307	*8,35,589*	*62,826*	44,149	*6,82,502*	*50,933*

(*a*) Estimated.

Clays.

The output of clays in 1937 was 348,099 tons, valued at Rs. 3,43,753 (£25,847) of which 330,007 tons were raised in India valued at Rs. 3,25,578 (£24,480). The Indian production in 1938 was 320,860 tons valued at Rs. 3,76,270 (£28,080), while the Burma output was 18,066 tons valued at Rs. 19,792 (£1,477). Practically the whole of the large production of Madras is from Travancore State for the manufacture of tiles and bricks.

TABLE 11.—*Production of Clays in India and Burma during 1937.*

—	1937.		
	Quantity.	Value (£1=Rs. 13·3).	
	Tons.	Rs.	£
India—			
Assam	18,383	6,894	518
Baroda	500	15,000	1,128
Bengal	25,669	36,988	2,781
Bihar	11,687	1,35,547	10,192
Central India	1,505	2,072	155
Central Provinces	47,967	27,999	2,105
Delhi	3,538	7,047	530
Gwalior	1,110	3,333	251
Kashmir	3	9	1
Madras (including Madras States)	104,547	21,066	1,584
Mysore	21,922	29,975	2,254
Orissa	10,193	24,300	1,828
Punjab	81,105	13,439	1,010
Rajputana	720	1,501	113
United Provinces	1,158	399	30
TOTAL	330,007	*3,25,578*	*24,480*
Burma	18,092	18,175	1,366

Figures for 1938 overleaf.

TABLE 12.—*Production of Clays in India and Burma during 1938.*

—	1938.		
	Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs.	£
India—			
Assam	23,251	8,719	656
Baroda	900	45,000	3,358
Bengal	23,230	31,852	2,377
Bihar	19,872	1,58,360	11,818
Central India	161	820	61
Central Provinces	60,252	43,383	3,237
Delhi	3,264	6,345	473
Gwalior	553	1,866	139
Kashmir	34	(a)	..
Madras (including Madras States)	116,973	19,861	1,482
Mysore	10,248	23,567	1,758
Orissa	8,991	19,293	1,439
Punjab	51,123	14,563	1,086
Rajputana	896	2,032	151
United Provinces	1,112	609	45
TOTAL	**320,860**	*3,76,270*	*28,080*
Burma	18,066	19,792	1,477

(*a*) Not available.

Coal.

In 1938 the total production of Indian coal rose to 28,342,906 tons or 3,306,622 tons (13·2 per cent.) increase on the output of the previous year and is thus the highest figure yet recorded. In the years 1931, 1932 and 1933 there had been a continuous decrease in production of coal from the then peak figure of 23,803,048 tons in 1930. In 1934 the direction of change was reversed and production increased by 2,268,284 tons (or 11·4 per cent.) from 19,789,163 tons in 1933 to 22,057,447 tons in 1934. In 1935 the increase continued but at a less rate, by 959,248 tons (or 4·3 per cent.), to 23,016,695 tons. In 1936 there was again a decrease by 405,874 tons (1·8 per cent.) to 22,610,821 tons, followed in 1937 by an increase of 2,425,565 tons (10·7 per cent.) to 25,036,386, the highest output till then, but which has now been greatly exceeded. This increase was shared by all provinces except Orissa, which showed a slight decrease. All the chief fields showed increased production

except Bokaro, Giridih, Umaria and Singareni, and the lesser fields of Jainti, Rampur (Orissa), Shahpur (Betul) and Shahpur (Punjab).

As usual the output of the Tertiary fields was but a trival proportion of the whole, the proportions being 98·17 per cent. from the Gondwana coalfields and 1·83 per cent. from the Tertiary coalfields.

The variations in the statistical position of the coal industry since 1927 can be gauged to some extent by examining the stock position at the end of each year. Stocks increased continuously from 1929 to 1932. In the 1933 review it was recorded that during 1933 the position showed no substantial change, but that the slight reduction of stocks might be sympotomatic of a tendency towards a better adjustment of production to demand. This surmise has proved to be partially correct, for during 1934 stocks were reduced by nearly 700,000 tons, increasing by 165,529 tons in 1935 and decreasing by 207,524 tons in 1936 and by 83,609 tons in 1937. In 1938 the stock shows a large increase of 1,369,490 tons. The data are given in the following table:—

Coal Stocks.

Year.	Opening Stock.	Closing Stock.	Reduction of stock.	Increase of stock.
	Tons.	Tons.	Tons.	Tons.
1927	2,161,806	1,721,288	440,518	..
1928	1,721,288	1,625,717	95,571	..
1929	1,625,717	844,240	781,477	..
1930	844,240	986,006	..	141,766
1931	986,006	1,414,340	..	428,334
1932	1,414,340	1,664,969	..	250,629
1933	1,664,969	1,646,248	18,721	..
1934	1,646,248	949,625	696,623	..
1935	949,625	1,115,154	..	165,529
1936	1,115,154	907,630	207,524	..
1937	907,630	824,021	83,609	..
1938	824,021	2,193,511	..	1,369,490

The increased output of 13·2 per cent. in 1938 was accompanied by an increase of 36·2 per cent. in the total value of the coal produced in India to Rs. 10,64,23,835 (£7,942,077) in 1938, from Rs. 7,81,02,439 (£5,872,364) in 1937.

Provincial production.

There was also an increase of 10 annas 2 pies in the pit's mouth value per ton of coal for India as a whole, namely from Rs. 3-1-11 to Rs. 3-12-1. This increase in value was recorded from all provinces without any exceptions (Table 14).

TABLE 13.—*Provincial production of Coal during the years 1937 and 1938 in Tons.*

—	1937.	1938.	Increase.	Decrease.
Assam	248,563	278,328	29,765	..
Baluchistan	17,479	21,882	4,403	..
Bengal	6,527,820	7,745,372	1,217,552	..
Bihar	13,836,717	15,364,079	1,527,362	..
Central India . . .	334,291	336,593	2,302	..
Central Provinces . . .	1,504,159	1,658,626	154,467	..
Eastern States Agency . .	1,244,988	1,463,693	218,705	..
Hyderabad	1,076,241	1,211,163	134,922	..
Orissa	47,127	44,425	..	2,702
Punjab	166,632	184,028	17,396	..
Rajputana	32,369	34,717	2,348	..
TOTAL .	25,036,386	28,342,906	3,309,222	2,702

TABLE 14.—*Value of Coal produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Value (£1 = Rs. 13·3).		Value per ton.	Value (Rs. 13·4).		Value per ton.
	Rs.	£	Rs. A. P.	Rs.	£	Rs. A. P.
Assam . . .	10,25,409	144,768	7 11 11	24,92,719	186,024	8 15 1
Baluchistan . .	1,09,713	8,249	6 4 5	1,43,910	10,739	6 9 8
Bengal . . .	2,10,13,790	1,579,984	3 3 6	3,10,96,838	2,820,650	4 0 3
Bihar . . .	4,09,23,918	3,076,986	2 15 4	5,37,10,370	4,008,237	3 7 8
Central India . .	11,77,547	88,537	3 8 4	13,71,920	102,382	4 1 8
Central Provinces .	40,80,150	374,447	3 4 11	61,18,233	456,585	3 11 0
Eastern States Agency	36,20,601	272,220	2 15 10	48,79,469	364,140	3 5 4
Hyderabad . .	32,17,860	241,944	2 15 11	52,75,033	393,659	4 5 8
Orissa . . .	1,50,528	11,318	3 2 4	1,44,002	10,746	3 3 10
Punjab . . .	8,36,790	62,917	5 0 4	10,20,856	76,183	5 8 9
Rajputana . .	1,46,133	10,988	4 8 8	1,70,485	12,723	4 14 7
TOTAL .	*7,81,02,439*	*5,872,364*	..	*10,64,23,835*	*7,942,077*	..
Average .	..	..	*3 1 11*	..	..	*3 12 1*

TABLE 15.- *of Indian Coal raised during the years 1937 and 1938 (in Tons).*

—	Average of last five years.	1937.	1938.
Gondwana coalfields	22,107,802	24,571,343	27,823,951
Tertiary coalfields	394,300	465,043	518,955
TOTAL	22,502,102	25,036,386	28,342,906

TABLE 16.—*Output of Gondwana Coalfields during the years 1937 and 1938.*

—	1937.		1938.	
	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.
Bengal, Bihar and Orissa—				
Bokaro	2,309,170	9·22	2,007,016	7·08
Giridih	674,794	2·70	636,371	2·24
Jainti	47,490	0·19	42,900	0·15
Jharia	9,601,230	38·35	11,144,462	39·32
Karanpura	534,328	2·14	625,914	2·21
Palamau (Daltonganj)	..	..	393	..
Rajmahal Hills	1,201	0·01	1,475	0·01
Rampur (Raigarh-Hingir)	47,127	0·18	44,425	0·16
Raniganj	7,196,324	28·74	8,650,920	30·52
Central India—				
Sohagpur	251,035	1·00	263,894	0·93
Umaria	83,256	0·33	72,699	0·26
Central Provinces—				
Ballarpur	264,269	1·05	279,353	0·98
Pench Valley	1,234,233	4·93	1,369,208	4·83
Shahpur (Betul)	5,657	0·03	5,288	0·02
Yeotmal	..	..	4,777	0·02
Eastern States Agency—				
Korea	850,701	3·39	1,012,858	3·58
Raigarh State	2,500	0·01	2,600	0·01
Talcher	391,787	1·56	448,235	1·58
Hyderabad—				
Kothagudam	1,176	0·01	95,248	0·34
Sasti	68,671	0·27	90,782	0·32
Singareni	740,770	2·96	690,850	2·43
Tandur	265,624	1·06	334,283	1·18
TOTAL	**24,571,343**	*98·13*	**27,823,951**	*98·17*

TABLE 17.—*Output of Tertiary Coalfields during the years 1937 and 1938.*

—	1937. Tons.	1937. Per cent. of Indian total.	1938. Tons.	1938. Per cent. of Indian total.
Assam—				
Khasi and Jaintia Hills .	7,648	1·00	16,660	0·98
Makum and Lakhimpur .	218,488		232,904	
Naga Hills . . .	22,427		28,764	
Baluchistan—				
Khost	6,262	0·07	7,165	0·08
Sor Range, Mach and Kalat	11,217		14,717	
Punjab—				
Jhelum	62,095	0·67	66,808	0·65
Mianwali	98,740		111,925	
Shahpur	5,797		5,295	
Rajputana—				
Bikaner	32,369	0·13	34,717	0·12
TOTAL .	**465,043**	*1·87*	**518,955**	*1·83*

The development of an iron and steel industry in India on modern lines has led to the erection of several plants for the manufacture of hard coke of metallurgical quality and it has therefore become a matter of general interest to know the proportion of the total annual output of coal in India that is utilised in the manufacture of hard coke. The figures for 1937 and 1938 are shown in Table 18.

Hard Coke.

TABLE 18.—*Quantity of Hard Coke produced in India during the years 1937 and 1938.*

—	1937(*a*).	1938.
Coal used	2,644,732	2,397,957
Hard coke manufactured	1,870,393	1,710,721
Percentage recovery	*70·72*	*71·34*

(*a*) Figures for 1937 have been revised.

TABLE 18.—*Quantity of Hard Coke produced in India during the years 1937 and 1938*—contd.

—	1937(*a*).	1938.
Sources of coal used—		
Jharia field	2,472,182	2,257,328
Giridih field	72,240	62,643
Raniganj field	83,925	63,742
Bokaro field	13,857	11,955
Lakhimpur (Namdang) field	2,528	2,289
TOTAL	2,644,732	2,397,957
Coal used for coking by—		
Two iron and steel companies	2,164,486	1,920,087
Others	480,246	477,870

(*a*) Figures for 1937 have been revised.

Exports.

In opposition to the trend of 1934, 1935 and 1936, the exports of coal from India in 1937 have more than doubled as compared with 1936, deducting Burma's share. Since the separation of Burma on the 1st April, 1937 it appears in these statistics as a foreign country, and in 9 months has taken a little more than Ceylon did in the year.

TABLE 19.- *Exports to Foreign Countries of Indian Coal and Coke during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value (£1 - Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
Ceylon	379,024	35,75,579	268,841	221,188	22,62,053	168,855
Burma	379,520	33,68,346	253,259	596,196	61,24,042	457,085
Straits Settlement	44,671	3,75,748	28,252	6,949	59,922	4,472
Hongkong	7,528	75,280	5,660	71,507	5,90,286	44,051
Other countries	45,352	4,18,898	31,496	425,512	40,65,045	303,361
TOTAL	**856,095**	*78,13,851*	*587,508*	**1,321,352**	*1,31,02,848*	*977,824*
Coke	17,215	3,26,131	24,521	21,681	4,47,761	33,415
TOTAL OF COAL AND COKE	**873,310**	*81,39,982*	*612,029*	**1,343,033**	*1,35,50,609*	*1,011,239*

The following table gives quantities of different grades of coal exported during 1937 and 1938 under the Indian Coal Grading Board's scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the

Coal Grading Board). There is an increase of 356,285 tons in the present year, the difference between the total amounts so exported (2,159,063 tons in 1938) and the total exports of Indian coal and coke to foreign ports given in Table 19 (1,343,033 tons in 1938) being the amount of coal exported to Indian ports.

TABLE 20. -*Exports of Coal under Grading Board Certificates during the years 1937 and 1938.*

	1937.	1938.
	Tons.	Tons.
Selected grade	1,702,181	2,070,885
Grade I	95,030	82,791
Grade II	3,074	..
Grade III	..	1,970
Mixed grade	2,493	3,417
TOTAL	1,802,778	2,159,063

Imports of coal and coke.

In reversal of the trend of previous years, imports of coal and coke showed increases during 1932 and 1933, namely from 47,544 tons in 1932 to 67,330 in 1933; 21,121 tons of the latter consisted of coke. 1934 showed a further slight increase to 72,161 tons, of which 14,719 tons were coke, and 1935 an increase to 77,075 tons, of which 12,791 tons were coke. In 1936 there was a further increase to 95,936 tons, of which 20,808 tons were coke but, in 1937, imports fell again to 64,850 tons, of which 3,305 tons were coke. The fall in imports continued in 1938 when 45,063 tons of coal and 1,677 tons of coke were imported into India. The fall is presumably due to the exclusion of coal imported into Burma. Imports of coal from the United Kingdom have fallen by over 9,500 tons (*see* Table 21). The total imports are now about a tenth of those of the pre-war quinquennium.

Table 22 shows the pre-war imports and exports with the figures from 1926 to 1938. It shows that the depression in the Indian coal industry, which reached its maximum in 1933, cannot be ascribed to the competitive effect of foreign imported coal. The average surplus of exports during the years 1926 to 1935 was, in fact, slightly greater than the surplus during the pre-war quinquennium, and the increase in 1938 is great, even allowing for the figures for export to Burma, which, before separation in 1937, were not included as exports.

TABLE 21.—*Imports of Coal and Coke during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
Australia	2,751	61,962	4,650	410	4,100	306
United Kingdom	22,536	4,78,332	35,965	13,018	2,87,586	21,462
Union of South Africa	10,918	3,12,767	23,516	23,170	4,40,099	32,843
Other Countries	16,340	2,48,612	18,693	8,465	1,48,592	11,089
TOTAL	61,545	*11,01,673*	*82,833*	45,063	*8,80,377*	*65,700*
Coke	3,305	1,11,680	8,397	1,677	78,983	5,894
TOTAL OF COAL AND COKE	64,850	*12,13,353*	*91,230*	46,740	*9,59,360*	*71,594*

TABLE 22.—*Excess of exports over imports of Coal (in Tons).*

—	Exports.	Imports.	Excess of exports over imports.
Average for 1909-13	814,475	466,162	348,313
1926	617,563	193,908	423,655
1927	576,167	243,603	332,564
1928	626,343	210,186	416,157
1929	726,610	218,560	508,050
1930	461,188	217,029	244,159
1931	441,249	88,035	353,214
1932	519,483	47,544	471,939
1933	426,176	67,330	358,846
1934	330,233	72,161	258,072
1935	217,584	77,075	140,509
1936	197,212	95,936	101,276
1937	873,310	64,850	808,460
1938	1,343,033	46,740	1,296,293

Persons Employed.

The average number of persons employed in the coalfields during the year showed an increase of 16·5 per cent. The average output per person employed showed a decrease from the high figure of 130·2 tons in 1934, which is practically the same as the figure for 1929, namely 130·4 tons, the highest figure recorded, to 124·92 tons in 1938 which is less than the figure 128·59 for 1937. The figures for the last nine years average higher than those previously recorded; these higher figures are partly due to an increased use of mechanical coal-cutters, and partly to concentration of work. During recent years a large number of collieries have been shut down and the labour absorbed in the

remainder; this concentration permits of a proportional reduction of the supervising staff, resulting in a larger tonnage per head. The fall in output per person employed in 1938 is of course due to increased employment.

There was a decrease in the number of deaths by accident from 274 in 1935, 435 in 1936 to 213 in 1937 but the number increased to 338 due to accidents in Bengal, Bihar and Hyderabad in 1938. In 1935 there were three major accidents, at Loyabad and Bagdigi collieries in the Jharia coalfield and at Kurhurbaree colliery in the Giridih coalfield, in which 11, 19 and 62 lives, respectively, were lost; in 1936 there were two, at Poidih in the Raniganj field, and Loyabad in the Jharia field, which accounted for 209 and 35 deaths respectively. These figures may be compared with the annual average for the quinquennium 1919-1923, which was 274, the annual average for the quinquennium 1924-1928, which was 218, and the annual average for 1929-1933, which was 186. The death rate was 1·09 per thousand persons employed in 1937 and 1·49 per thousand in 1938; the average figure for the period 1919-1923 was 1·36, for the period 1924-1928 was 1·16, and for the period 1929-1933 was 1·08.

TABLE 23.—*Average number of persons employed daily in the Indian Coalfields during the years 1937 and 1938. Also output per person, death rate, etc., for 1938.*

—	1937.	1938.	Output per person employed in tons.	Number of deaths by accident.	Death rate per 1,000 persons employed.
Assam	2,091	2,361	117·88	8	3·39
Baluchistan	393	602	36·35	..	..
Bengal	51,077	59,364	130·47	109	2·13
Bihar	103,195	122,137	125·79	92	1·84
Central India	2,571	2,811	119·74	4	1·42
Central Provinces	11,918	13,771	120·44	31	2·25
Eastern States Agency	8,279	10,426	140·39	..	..
Hyderabad	12,308	11,281	107·36	86	7·62
Orissa	322	365	121·71	..	..
Punjab	2,399	2,747	66·09	8	2·91
Rajputana	152	1,012	34·31	..	..
Sind	..	10	..	..	..
TOTAL	**194,705**	**226,887**	..	**338**	..
Average	..	..	*124·92*	..	*1·49*

Cobalt.

The nickel speiss from the Namtu smelter of the Burma Corporation, Limited, contains 6·69 per cent. of cobalt. In 1938, 3,015 tons of the speiss were produced. (*See* Nickel, p. 325).

Burma.

Copper.

The progress of work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, and on the milling and smelting plant at Maubhandar, near Ghatsila, Bengal Nagpur Railway, has been noticed in previous Reviews. Operations commenced on a revenue basis on January 1st, 1929, and the progress of the industry until 1933 is summarised in the Quinquennial Review for 1929-1933. Together with an improvement in market price the production of both mine and smelter has continued to expand. In addition, from 1933 onwards, there has been production of ore from Dhobani, where a lode parallel to that at Mosaboni is being opened up. During 1938 operations extended to five mines and the total output of ore was 288,076 long tons valued at Rs. 32,40,640 (£243,048) as compared with 371,458 long tons valued at Rs. 48,69,790 (£366,150) in 1937. The total output for 1938 was obtained as follows:—

Singhbhum (Bihar).

	Long tons	as against	Long tons in 1937.
Mosaboni	255,383	" "	335,859
Dhobani	25,183	" "	30,986
Badia	910	" "	4,012
Surda	6,600	" "	601
	288,076		371,458

The smaller output in 1938 is due to a strike at the mines which lasted from the 12th April to the 20th July, 1938.

A total of 296,924 short tons of ore was treated in the mill, at a valuation of Rs. 31,46,036, and the production of refined copper amounted to 5,330 long tons against 6,830 long tons in the previous year. A total of 5,527 tons of copper ingots was consumed in the rolling mill and 101 tons were sold in the Indian market at an average price of Rs. 826 per ton *f.o.r.* Ghatsila. Operations in the rolling mill resulted in the production of 8,236 long tons of yellow metal

sheet and 1,127 long tons of yellow metal circles, the whole of which was sold in India at average prices of Rs. 705 and Rs. 787 respectively per ton.

The total ore reserves at the close of the year 1938 amounted to 852,300 short tons, with an average assay value of 2·88 per cent. of copper, against 946,000 short tons, with an average assay value of 2·91 per cent. of copper, at the end of 1937. The Indian Copper Corporation reached the dividend-paying stage in 1933.

Mysore. An output of 51 tons of copper ore, valued at Rs. 101 (£8), is reported from Mysore.

Burma. There was a decrease in the production of copper matte at the Namtu smelting plant of the Burma Corporation, Limited, from 7,750 tons valued at Rs. 24,18,465 (£181,839) in 1937 to 5,900 tons valued at Rs. 16,11,091 (£120,230) and averaging 42·46 per cent. of copper, 28·76 per cent. of lead and 71·61 ozs. of silver to the ton. Included in the ore-reserves in the Bawdwin mine of the Burma Corporation are approximately 330,000 tons of copper-ore.

Corundum.

The production of corundum in the Salem district, Madras, amounted to 28 tons valued at Rs. 6,181 (£465) in 1935 and in 1936 the output was 1½ tons valued at Rs. 420 (£32). No production was recorded in 1937. The production in 1938 was 50 cwts. valued at Rs. 250 (£19), 10 cwts. from Salem and 40 cwts. from Mysore. There was an output of 634 tolas of corundum from Soomjam, Padar district, Kashmir, in 1938 as against 1,869 tolas from the same area in 1937. (*See* also Sapphire, p. 332).

Diamonds.

The production of diamonds in Central India rose from 1,178 carats valued at Rs. 54,979 (£4,134) in 1937 to 1,729 carats valued at Rs. 68,813 (£5,135). Of this latter production 1,688 carats were produced in Panna State and the remainder in Charkhari (7 carats) and Ajaigarh States (34 carats).

Felspar.

The output of felspar in 1934 was 628 tons valued at Rs. 6,311 (£474), which rose in quantity to 702 tons in 1935, with a fall in value,

however, to Rs. 4,943 (£372), rising again to 784·5 tons valued at Rs. 6,037 (£454), in 1936 and falling to 487 tons, valued at Rs. 3,390 (£255) in 1937. The details of production for 1937 and 1938 are shown below :—

—	1937.			1938.		
	Tons.	Value.		Tons.	Value.	
		Rs.	£ (Rs. 13·3)		Rs.	£ (Rs. 13·4)
Mysore State . .	143	858	65	..	..	..
Rajputana—						
Alwar State . .	76	665	50	86	790	59
Ajmer-Merwara . .	268	1,867	140	605	3,545	265
TOTAL .	**487**	*3,390*	*255*	**691**	*4,335*	*324*

Fuller's earth.

There was a rise in the reported production of fuller's earth from 7,416 tons valued at Rs. 75,017 (£5,640) in 1937 to 8,059 tons valued at Rs. 78,958 (£5,892) in 1938. The increase was mainly from Bikanir State.

TABLE 24.—*Quantity and value of Fuller's earth produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£ (Rs. 13·3)	Tons.	Rs.	£(Rs. 13·4)
Central Provinces—						
Jubbulpore . . .	45	67	5	58	87	6
Punjab States Agency—						
Khairpur State . .	4,844	(*a*) 48,440	3,642	4,665	(*a*) 46,650	3,481
Rajputana—						
Bikaner State . .	869	8,315	625	1,584	13,050	974
Jaisalmer State . .	18	195	15	15	165	12
Jodhpur State . .	1,640	18,000	1,353	1,737	19,000	1,419
TOTAL .	**7,416**	*75,017*	*5,640*	**8,059**	*78,958*	*5,892*

(*a*) Estimated.

Garnet sand.

In 1937 there was an output of about 330 tons of garnet sand valued at Rs. 1,650 (£124) from Tinnevelly district, Madras. In 1938 this fell to 120 tons valued at Rs. 600 (£45) from the same area,

Gold.

In 1938 the output decreased slightly to 321,137·8 ozs. valued at Rs. 3,04,75,397 (£2,274,283) from 330,743·9 ozs. valued at Rs. 3,03,95,871 (£2,285,404) (Table 25).

All fields shared in this decrease, except the United Provinces. Of the four mines that are producing gold in the Kolar Gold Field,

India.

the Champion Reef and the Ooregum Mines, the two deepest on the field, reached vertical depths of 8,361 feet and 8,130 feet respectively below field datum (2,967·21 feet above Madras sea-level) on the 31st December, 1938. The development in depth has disclosed the continuity of the reef, and payable ore continues to be opened up resulting in increased ore reserves. At these depths the dip of the reef is almost vertical. The ore is not refractory and yields its gold to blanket concentration and cyaniding; 'all-sliming' practice is becoming general. The concentrates are pan- or plate-amalgamated.

The rock temperature at the deepest working place was 133°F. Owing to the great depths of these mines and the consequent high temperatures, the maintenance of adequate ventilation at the working places is extremely difficult, and it has been partly solved by sinking deep, smooth-lined vertical shafts, circular or elliptical, and by an extensive use of large electrically-driven fans erected in suitable places to aid the movement of air underground to ensure an adequate supply to working places. In order to further improve the condition in the lowest levels, the Ooregum Mine installed, in 1938, an air-conditioning plant of the ammonia compressor type using brine in coil type coolers. It is situated on the surface at the top of the main down-cast shaft and is of sufficient capacity to cool 150,000 cubic feet of air per minute from an incoming temperature of 73°F. wet bulb to 40°F. saturation. The working of this plant has resulted in a considerable reduction of air temperatures underground with a corresponding increase in efficiency.

Though rock-bursts cannot be eliminated altogether in deep mining, the more rigid forms of support, such as packs of masonry and concrete, and sand or waste rock filling, which are generally used in these mines, have resulted in the reduction of the number of heavier rock-bursts, which were causing considerable damage to persons and property in the past.

The average number of persons employed on the Kolar Gold Field during 1938 was 24,031, of whom 15,528 worked underground.

The Burma output increased appreciably, owing principally to a rise in production from 894 ozs. to 1,063 ozs. from the operations of the Burma Corporation in the Northern Shan States. But these figures are, of course, quite insignificant compared with the output of Kolar, which makes up 99·6 per cent. of the India and Burma total.

Burma.

The considerable increase in the value of the production in 1932 was due to that being the first full year since Britain and India abandoned the gold standard in September, 1931, with consequent appreciation in the price of gold against sterling or rupees. As a result of this appreciation, 9,766,122 ozs. of gold reckoned in terms of fine gold and valued at Rs. 75,87,52,203 (£57,049,038) were exported during 1932. In 1933 the exports were 6,248,095 ozs. valued at Rs. 51,25,48,810 (£38,537,505), in 1934 they were 6,685,900 ozs. valued at Rs. 60,50,74,489 (£45,494,323), in 1935 4,732,185 ozs. valued at Rs. 44,22,27,875 (£33,250,216), in 1936 3,588,117 ozs. valued at Rs. 33,15,99,305 (£24,932,279), in 1937 1,971,126 ozs. valued at Rs. 18,27,80,654 (£13,742,906), and in 1938 1,649,589 ozs. valued at Rs. 15,59,88,285 (£11,640,917).

Exports.

TABLE 25.—*Quantity and value of Gold* produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value.		Quantity.	Value.	
	Ozs.	Rs.	£ (Rs. 13·3)	Ozs.	Rs.	£ (Rs. 13·4)
India—						
Bihar	26·0	1,645	124	16·0	996	74
Mysore	330,710·2	3,03,93,539	2,285,229	321,114·8	3,01,73,769	2,274,162
Punjab	5·8	537	40	4·0	372	28
United Provinces	1·0	150	11	3·0	260	19
TOTAL	**330,743·9**	*3,03,95,871*	*2,285,404*	**321,137·8**	*3,01,75,397*	*2,274,283*
Burma—						
Katha	31·1	3,005	226	45	3,116	232
Upper Chindwin	70·2	9,483	713	101	12,113	904
Northern Shan States	894·0	71,746	5,394	1,063	89,915	6,710
TOTAL	**1,004·3**	*84,234*	*6,333*	**1,209**	*1,05,144*	*7,846*

* Fine ounces.

Graphite.

In 1935 there was an output of 557 tons of graphite valued at Rs. 11,481 (£863), composed of 406 tons valued at Rs. 9,274 from

Betul district, C. P., 150 tons valued at Rs. 2,157 from Kolar district, Mysore, and 1 ton valued at Rs. 50 from Vizagapatam district, Madras. In 1936 this fell to 388 tons valued at Rs. 4,400 (£331), 237 tons valued at Rs. 1,380 being from Betul district and 151 tons valued at Rs. 3,020 from Kolar district. In 1937 there was no production from Betul district, but 228 tons, valued at Rs. 8,892 (£669) from Patna State, Eastern States Agency, 10 tons valued at Rs. 1,000 (£75) from Vizagapatam, and the Kolar output more than doubled, to 320 tons, valued at Rs. 6,410 (482), the total being 558 tons. The output for 1938 is shown below:—

—	Tons.	Value.	
		Rs.	£ (Rs. 13·4)
Central Provinces—			
Betul	20	981	73
Eastern States Agency—			
Patna State	438	19,710	1,471
TOTAL .	458	*20,691*	*1,544*

Gypsum.

There was a large rise of 23,733 tons, but at a depreciated value, in the output of gypsum, from 46,090 tons valued at Rs. 1,18,543 (£8,913) in 1937 to 69,823 tons valued at only Rs. 1,71,903 (£12,829) in 1938.

TABLE 26.—*Quantity and value of Gypsum produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£ (Rs. 13·3)	Tons.	Rs.	£ (Rs. 13·4)
Kashmir State	7	44	3	40	280	21
Madras—						
Trichinopoly	1,597	15,603	1,173	9,356	65,781	4,909
Punjab—						
Jhelum	25,846	36,859	2,771	28,266	42,730	3,180
Rajputana—						
Bikaner State	7,108	40,265	3,028	19,932	35,280	2,633
Jaisalmer State . . .	265	1,010	76	261	1,002	74
Jodhpur State . . .	11,000	24,000	1,805	10,800	23,500	1,754
United Provinces—						
Garhwal	267	702	57	1,168	3,330	249
TOTAL .	**46,090**	*1,18,543*	*8,913*	**69,823**	*1,71,903*	*12,829*

Ilmenite.

There was a large increase in the production of ilmenite in Travancore State from 75,644 tons valued at £39,245[1] in 1934 to 127,051 tons valued at £58,789 in 1935, to 140,477 tons valued at £62,418 in 1936, and again to 181,047 tons, valued at Rs. 11,26,329 (£84,686) in 1937, and this again has been exceeded in 1938 when the production rose to 252,220 tons valued at Rs. 15,46,436 (£115,406)—the highest output yet recorded. Since 1927 India has been the world's largest producer of ilmenite. This mineral occurs in the monazite sands and, up to a few years ago, was looked upon as a by-product of the monazite industry. The monazite sands have been worked continuously since 1911, but it was not until 1922 that the export of ilmenite commenced, since when the production of the mineral has expanded almost continuously, so that in both quantity and value the production of ilmenite is now much more important than that of the associated minerals monazite and zircon. This steady increase in the output of ilmenite is due to the demand for its content of titanium dioxide in the manufacture of titanium paints. The exports of ilmenite were 106,585 tons in 1935, 123,799 tons in 1936, 204,653 tons in 1937, and 225,592 tons in 1938.

Iron and Steel.

Iron-ore.

For some years up to and including 1929 the production of iron-ore in India had been steadily increasing; India is now, in fact, the second largest producer in the British Empire, and yields place only to the United Kingdom. Her output is of course still completely dwarfed by the production in the United States (30½ million tons in 1935 and 48¾ million tons in 1936) and France (32·3 million tons in both 1935 and 1936); but her reserves of ore are not much less than three-quarters of the estimated total in the United States and there is every hope that India will eventually take a much more important place among the world's producers of iron-ore. From 2,430,136 tons in 1929 the output of iron-ore in India fell to 1,228,625 tons in 1933. In 1934, however, there was a turn of the tide and the production recovered sharply to 1,916,918 tons, and in 1935 rose still further to 2,364,297 tons, in 1936 to 2,553,247 tons, in 1937, to 2,870,832 tons valued at Rs. 45,86,378 (£344,840), but in 1938 the production fell slightly to

[1] Revised value.

2,743,675 tons valued at Rs. 45,56,974 (£340,073). These figures exclude the output of about 25,000 tons, by the Burma Corporation, which is used as a flux in lead-smelting. As will be seen later, there were also substantial increases in the output of pig-iron and steel.

The figures shown against the Keonjhar and Mayurbhanj States in Table 27 represent the production by Bird & Co., and the Tata Iron and Steel Co., Ltd., respectively. Of the total production of 1,418,834 tons in 1938 shown against Singbhum, 605,141 tons were produced by the Tata Iron and Steel Co., Ltd., 778,793 tons by the Indian Iron and Steel Co., Ltd., and the remaining 34,900 tons by small concerns. The production from the Central Provinces has nearly doubled since 1937 though the output for 1938 is still small—611 tons.

TABLE 27.—*Quantity and value of Iron-ore produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£ (Rs. 13·3)	Tons.	Rs.	£ (Rs. 13·4)
India—						
Bihar— Singhbhum	1,587,362	27,30,077	205,269	1,418,834	26,79,139	199,936
Palamau	..	..	..	2,256	10,857	810
Central Provinces	354	1,062	80	611	1,833	137
Eastern States Agency—						
Keonjhar State	307,935	3,18,646	23,958	494,080	5,19,893	38,798
Mayurbhanj State	942,701	14,31,760	107,651	791,367	12,30,200	91,806
Mysore State	32,480	1,04,833	7,882	35,627	1,15,052	8,586
TOTAL	**2,870,832**	*45,86,378*	*344,840*	**2,743,675**	*45,56,974*	*340,073*
Burma— Northern Shan States	25,426	(a)1,01,704	7,647	18,050	(a)72,200	5,388

(a) Estimated.

The production of pig-iron by the Tata Iron and Steel Co., at Jamshedpur rose to 988,345 tons in 1938 from 885,393 tons in 1937, while their steel production rose to 693,064 tons in 1938 from 665,309 tons in 1937. The production of ferro-manganese rose to 18,385 tons in 1938 from 8,041 tons in 1937.

Pig-Iron.

The pig-iron made by the Tata Iron and Steel Co., Ltd., during 1937 and 1938 was used as follows :—

——	1937.	1938.
	Tons.	Tons.
Pig-iron for Duplex Plant Bessemer Converters .	653,024	706,414
„ for Open Hearth	148,578	145,155
„ for sale and use in foundries . .	69,497	121,718
Molten pig used for direct castings . . .	14,294	15,058
TOTAL .	885,393	988,345

The pig-iron is graded as follows :—

(*a*) Standard Foundry Nos. 1, 2, 3 and 4.

(*b*) Special No. 4X.

(*c*) Special Basic.

(*d*) Standard Basic.

(*e*) Low manganese Foundry Nos. 1, 2, 3, 4 and 4X.

(*f*) Low manganese Basic special.

(*g*) Low manganese Basic.

(*h*) High manganese Basic.

During 1936 the Indian Iron and Steel Co. and the Bengal Iron Co. amalgamated and the output of pig-iron by the combined company increased from 659,543 tons in 1936 to 713,030 tons in 1937, but fell to 540,277 tons during 1938.

TABLE 28.—*Production of Pig-iron by the Indian Iron and Steel Company, Limited, during 1937 and 1938 (in Tons).*

——	1937.	1938.
Foundry	492,929	420,553
Basic quality	214,278	116,576
Speigeleisen	327	..
High Silicon	5,496	3,148
TOTAL .	713,030	540,277

60,275 tons of iron castings were produced in 1937 and 27,541 tons in 1938 by the Indian Iron and Steel Co. at their Kulti Works.

The output of charcoal pig-iron by the Mysore Iron and Steel Works fell to 11,267 tons in 1938 from 22,837 tons in 1937.

The total production of pig-iron in India fell to 1,539,889 tons in 1938 from 1,621,260 tons in 1937, and is shown in Table 29.

TABLE 29.—*Production of Pig-iron in India during the years 1937 and 1938 (in Tons).*

—	1937.	1938.
The Tata Iron and Steel Company, Limited .	885,393	988,345
The Indian Iron and Steel Company, Limited .	713,030	540,277
The Mysore Iron and Steel Works	22,837	11,267
TOTAL .	**1,621,260**	**1,539,889**

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1938 for the purpose of smelting iron-ore was 136 against 110 in the previous year; 59 furnaces were operating in the Bilaspur district, 21 in Mandla, 50 in Raipur and 6 in Drug. In 1937 there were 3 Agaria furnaces in Raipur. The production of iron-ore in Palamau also suggests the rejuvenation of indigenous smelting operations.

Agaria furnaces.

The decrease in the production of pig-iron in India recorded above was accompanied by a slight fall in the quantity exported, to 525,254 tons in 1938 from 597,331 tons in 1937. The value, however, increased very appreciably. Table 30 shows that Japan is still the principal consumer of Indian pig-iron; the quantity in 1938 increased by 41,298 tons, 14·65 per cent.; the proportion taken fell from 70·8 per cent. in 1935 to 60·6 per cent. in 1936, 47·2 per cent. in 1937 and has risen to 61·5 per cent. in 1938. There was a large fall in exports to the United Kingdom (which took 24·7 per cent. of the exports) and greater still to the United States. The exports to China have stopped, while the amount taken by other countries has more than doubled. The export value per ton of pig-iron rose to Rs. 50·1 (£3·70) in 1938 from Rs. 34·5 (£2·6) in 1937.

Exports of Pig-iron.

The Steel Industry (Protection) Act, 1924 (Act No. XIV of 1924) authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from materials wholly or mainly produced from Indian iron-ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a

Steel production.

substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March, 1927; the industry is, however, protected to a certain extent by the varying tariffs on different classes of imported steel. As a result of a new Act, No. XXXI of 1934, provision has been made for an increase of tariffs by about half over the 1927 rates, or about Rs. 10 per ton *ad valorem* in most cases, or about Rs. 40 per ton in the case of articles not of British manufacture.

TABLE 30.—*Exports of Pig-iron from India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£ (Rs. 13·3)	Tons.	Rs.	£ (Rs. 13·4)
To—						
China	6,766	1,81,528	13,649	..	..	..
Japan	281,748	95,53,412	718,302	323,046	1,60,85,506	1,200,411
United Kingdom	215,801	77,13,808	579,990	129,824	66,09,976	493,282
United States of America	68,013	23,85,623	179,370	6,441	2,96,592	22,133
Other countries	25,003	7,64,147	57,454	65,943	32,91,965	245,669
TOTAL	**597,331**	*2,05,98,578*	*1,548,765*	**525,254**	*2,62,84,039*	*1,961,495*

Out of a total of 1,539,889 tons of pig-iron in 1938 the steel industry absorbed 851,569 tons leaving 688,320 tons available for export and domestic use. If we value this pig-iron at the export price, Rs. 50 the value of the available pig-iron of 1938 is Rs. 3,44,16,000 (£2,568,358) or about eight times the value of the whole iron-ore production. Similarly the value of the 693,064 tons of steel, for steel rails, etc., produced in 1938 valued at a nominal figure of Rs. 100·5 (£7-10) a ton, has a value of Rs. 6,96,52,932 (£5,197,980) or fifteen times that of the total iron-ore production. In addition the 18,385 tons of ferro-manganese made in India in 1938 estimated at a nominal figure of Rs. 134 (£10) per ton has a value of Rs. 24,63,590 (£183,850). There is little doubt that all the values are greatly underestimated but notwithstanding this the value of the metallic products made from the iron-ore production of India are not less than 25 times

Value of products.

more valuable than the original ore. The corresponding figures for 1937 are available: pig-iron 819,658 tons at Rs. 34·5, Rs. 2,82,78,201 (£2,126,180), steel 665,309 tons at Rs. 100·5, Rs. 6,68,63,554 (£5,027,334). Ferro-manganese 8,041 tons at £10, Rs. 10,69,453 (£80,410). Total pig-iron and steel £7,158,445 as against value of iron-ore £344,840 which is 20 times less valuable on the conservative value for pig-iron and steel.

Jadeite.

There was a decrease in the output and the value of jadeite from the Myitkyina district, Burma, from 2,952 cwts. valued at

Burma.

Rs. 1,73,304 (£13,030) in 1937 to 1,303 cwts. valued at Rs. 57,891 (£4,320) in 1938. Exports by sea fell from 2,410 cwts., valued at Rs. 1,28,912 (£9,693) in 1937 to only 204 cwts. valued at Rs. 18,808 (£1,405) presumably due to stoppage of trade with China. These shipments were entirely from Burma.

Kyanite, etc.

The output of kyanite and quartzite and similar rocks in Singhbhum district, Bihar, and Kharsawan State of the Eastern States Agency, is partly for purposes of export, and partly for use in India, such as for furnace linings at Jamshedpur. The data for 1937 and 1938 are assembled in Table 31, from which it will be seen that there has been an increase in total output from 45,158 tons, valued at Rs. 7,08,623 (£53,280) in 1937 to 48,743 tons valued at Rs. 7,46,514 (£55,710).

The most valuable of these materials is kyanite extracted for export by the Indian Copper Corporation from Lopso Hill in Kharsawan. In the year under review the sources of Kyanite were as follows:—27,359 tons from Kharsawan State, 194 tons from Seraikela State, 830 tons from Singhbhum and 2 tons from Ajmer-Merwara. The quartzite was produced in Singhbhum (11,991 tons), and Seraikela State (3,700 tons). The output of quartz mica schist from Singhbhum was 4,504 tons. An output of 163 tons of sillimanite, which occurs in the form of sand, was recorded from Travancore State.

TABLE 31.—*Quantity and value of Kyanite, Quartzite Sillimanite and Quartz-mica Schist produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value. £ (Rs. 13-3).		Quantity.	Value £ (Rs. 13-4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Kyanite	(a)26,936	6,49,092	48,804	28,385	6,80,169	50,759
Quartz-mica Schist	3,025	31,400	2,361	4,504	35,187	2,626
Quartzite	15,197	28,131	2,115	15,691	28,985	2,163
Sillimanite sand	..	..	..	163	2,173	162
TOTAL	45,158	*7,08,623*	*53,280*	48,743	*7,46,514*	*55,710*

(*a*) Revised.

Lead.

The production of lead-ore at the Burma Corporation's Bawdwin mines in Burma fell slightly to 472,100 tons valued at Rs. 63,14,092 (£471,201) in 1938, from 476,986 tons, valued at Rs. 1,28,24,215 (£964,227), in 1937, whilst the total amount of metal extracted rose slightly from 77,650 tons (including 1,150 tons of antimonial lead) valued at Rs. 2,43,83,836 (£1,833,371) in 1937 to 80,100 tons (including 1,200 tons of antimonial lead) valued at Rs. 1,67,36,720 (£1,249,009). The value of the antimonial lead is Rs. 2,96,090 (£22,096).

Burma.

The quantity of silver extracted from the Bawdwin ores fell from 6,180,000 ozs. valued at Rs. 73,60,998 (£553,458) in 1937 to 5,920,000 ozs. valued at Rs. 68,83,184 (£513,670). The value of the lead per ton fell from Rs. 318·7 (£23·96) to Rs. 208·95 (£15·59), whilst the value of the silver per ounce fell from Re. 1-3-1 (21·49*d.*) to Re. 1-2-7 (20·82*d.*) in the year under review. The ore reserves in the Bawdwin mine as calculated on the 30th of June, 1938 totalled 3,764,658 tons against 3,863,548 tons at the end of June, 1937, with an average composition of 23·1 per cent. of lead, 14·0 per cent. of zinc, 0·94 per cent. of copper, and 17·7 ozs. of silver per ton of lead. Included in this are 330,000 tons of copper ore.

Silver in Lead.

Magnesite.

The output of magnesite from Salem district fell slightly, while there was an increase of 175 tons from Mysore State.

TABLE 32.—*Quantity and value of Magnesite produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13-3).		Quantity.	Value £ (Rs. 13-4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Salem	23,782	1,40,708	10,580	23,052	1,34,876	10,065
Mysore State	2,384	23,230	1,746	2,559	25,717	1,919
TOTAL .	**26,166**	*1,63,938*	*12,326*	**25,611**	*1,60,593*	11,984

Manganese.

Review of progress.

The full magnitude of the catastrophe* to the Indian manganese industry six years ago is perhaps best realised from the fact that whilst the quantity of the production in 1933 was a little over one-fifth of that of the peak year of 1927, the value was less than one-twenty-second part of the value of the 1927 production. In fact in none of the major Indian mineral industries had the effects of the slump been so seriously felt as in the manganese industry; it is gratifying therefore, that a recovery has since been recorded which approaches the peak output of 1927, with a much higher value. In 1934 there was, however, a partial recovery to 406,306 tons valued at £388,240; the output further increased in 1935 to 641,483 tons valued at £768,630, in 1936 to 813,442 tons valued at £1,124,422 and in 1937 to 1,051,594 tons valued at £3,229,554 but in 1938 there was a fall in output and prices to 967,929 tons valued at £2,932,445.

* The catastrophic fall in the production of manganese-ore in India from the peak figures of 1927, namely 1,129,353 tons valued at £2,703,068 f.o.b. Indian ports, to 212,604 tons with a value of £140,022 in 1932 has been recorded in previous Reviews. In 1933 the output rose slightly to 218,307 tons but the value fell to £123,171. These are the smallest quantities and values reported since 1901, when the output was 120,891 tons valued at £122,831. In 1905 the output was 247,427 tons valued at £223,432, since when the smallest production was 450,416 tons in 1915, valued at £929,546; whilst the smallest value was in 1909 when a production of 644,660 tons was valued at £603,908.

The recovery in 1936 has been set back by decreases in the Balaghat and Bhandara districts of the Central Provinces, Keonjhar in the Eastern States Agency and in North Kanara (Bombay), the Sandur State (Madras) and in the Chitaldrug and Shimoga districts of Mysore State. There has been an improvement in the production from the Panch Mahals, Chhindwara, Bellary, Tumkur and Vizagapatam as seen in Table 33. During 1932 and 1933 the majority of mines in the Central Provinces had been closed, including several mines that had never been closed since the commencement of work in 1900 and 1901; there had been a total cessation of production in the Nagpur district and almost total cessation in Bhandara. The amount of ground recovered can be judged from the fact that the production of the Central Provinces averaged 660,559 tons annually during the quinquennium 1924 to 1928. All producing districts are now actively engaged in the output of manganese-ore.

The fall in the Indian output of manganese-ore of recent years can be correlated with the fall in the price of firstgrade ore, *c.i.f.* United Kingdom ports, from an average of 22·9*d.* per unit in 1924 to 14·9*d.* per unit in 1929, and then to 9·5*d.* per unit in 1932 and 1933. A partial recovery in output in 1934 accompanied a rise in the average price to 10·5*d.* per unit, and to 12·26*d.* in 1936, rising as high as 22·5*d.* in 1937, but in 1938 the price fell to 19·7*d.* per unit.

Price of Ore.

The present chief sources of production of manganese-ore are Russia, India, the Gold Coast, South Africa, Brazil, Cuba, Egypt, Czechoslovakia and Japan. Russia is able to place large quantities of ore on the market at a price with which many Indian producers cannot compete without a return to pre-war railway freights. The Gold Coast has also become a serious competitor of recent years. The large deposits of high-grade manganese-ore discovered near Postmasburg in South Africa are also being developed.

There is a steady consumption of manganese-ore at the works of the two principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Company, and for the manufacture of ferro-manganese, but also for addition to the blast-furnace charges in the manufacture of pig-iron. The consumption of manganese-ore by the Indian iron and steel industry in the year under review amounted to 63,731 tons as against 60,219 tons in 1937 and 46,221 tons in 1936.

TABLE 33.—*Quantity and value of Manganese-ore produced in India during the years 1937 and 1938.*

—	1937.		1938.	
	Quantity.	Value f.o.b. at Indian ports.	Quantity.	Value f.o.b. at Indian ports.
	Tons.	£	Tons.	£
Bihar—				
Singhbhum	24,180	77,376	24,469	73,611
Bombay—				
North Kanara	18,723	59,914	12,204	36,714
Panch Mahals	41,041	131,331	49,394	148,594
Central Provinces—				
Balaghat	399,532	1,353,414	368,300	1,169,350
Bhandara	153,230	519,066	129,630	413,735
Chhindwara	1,048	3,530	4,401	13,973
Nagpur	141,367	478,880	144,134	457,625
Eastern States Agency—				
Bonai	13,856	35,217	14,790	40,857
Keonjhar	82,128	208,742	64,901	219,288
Madras including Madras States—				
Bellary	450	913	2,000	4,542
Kurnool	200	423	..	..
Sandur State	149,782	303,933	116,574	264,715
Vizagapatam	20,509	45,120	31,809	76,909
Mysore—				
Chitaldrug	2,841	5,993	829	1,952
Shimoga	2,207	4,644	646	1,521
Tumkur	500	1,058	3,848	9,059
TOTAL	**1,051,594**	*3,229,554*	**967,929**	*2,932,445*

The partial recovery of the Indian manganese industry during 1934 and 1935 was reflected in an increase of exports, including the quantities exported from Mormugao in Portuguese India, from the nadir of 275,904 tons in 1933 to 864,698 tons in 1935. In 1936 this fell to 742,547 tons, and after rising to 1,151,834 tons in 1937 fell to 648,740 tons in 1938.

Exports.

Table 34 shows the distribution of manganese-ore exported from British Indian ports and Mormugao during 1937 and 1938, and from Table 35 it will be seen that the United Kingdom even with a decrease of over 127,000 tons retained her position as the chief importer of Indian manganese-ore. The second place as importer was taken by Japan with

113,212 tons, with the U. S. A. third with 89,037 tons and France a close fourth with 80,950 tons. The Belgium and German figures show a marked decrease.

TABLE 34.—*Exports of Manganese-ore during 1937 and 1938 according to ports of Shipment in Tons.*

——	1937.	1938.
Bombay	130,837	60,679
Calcutta	316,767	137,682
Vizagapatam	533,585	319,081
Mormugao (Portuguese India)	170,645	130,398
TOTAL	**1,151,834**	**648,740**

TABLE 35.—*Exports of Manganese-ore from British Indian Ports during the years 1937 and 1938.*

——	1937.			1938.		
	Quantity.	Value £(Rs. 13-3).		Quantity.	Value £(Rs. 13-4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom	272,265	57,72,092	433,992	145,086	31,37,234	234,122
Germany	18,035	4,82,919	36,310	3,609	1,61,064	12,020
Netherlands	18,412	3,45,497	25,077	350	22,607	1,687
Belgium	137,437	32,08,901	241,271	8,962	3,46,406	25,851
France	185,203	42,09,414	316,497	80,950	15,81,593	118,029
Italy	19,114	4,40,967	33,155	48,150	17,68,200	131,955
Japan	178,547	32,80,694	246,669	113,212	23,11,843	172,526
United States of America	143,102	29,07,982	218,615	89,037	18,28,880	136,483
Other countries	9,074	1,90,600	14,331	28,986	7,91,644	59,078
TOTAL	**981,189**	*2,08,39,066*	*1,566,847*	**518,342**	*1,19,49,471*	*891,751*

Mica.

There was a rise in the declared production of mica to 123,169 cwts. valued at Rs. 42,04,633 (£313,779) in 1938 from 104,658 cwts., valued at Rs. 39,50,281 (£297,014) in 1937. As has been frequently pointed out the output figures are incomplete and a more accurate idea of the size of the industry is to be obtained from the export figures. (See Tables 36 and 37.) The difference between exports and production has generally been attributed to theft from the mines, but the production recorded is for dressed mica only

whereas the exports include, as well as this, much material recovered from dumps, splittings and waste mica, and mica won in *Zamindaries* and in prospecting. This, as well as any stolen mica, makes up the discrepancy.

Exports.

The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed respectively 28·0 per cent. and 31·0 per cent. during 1938, as against 62·3 per cent. and 22·1 per cent. during 1937. Germany took 17·0 per cent. and Japan took 13·0 per cent. respectively, of the total quantities exported during the year 1938. The average value of the exported mica which decreased from Rs. 51·7 (£3·9) per cwt., in 1936 to Rs. 48·3 (£3·6) in 1937 rose to the high value of Rs. 64·7 (£4·8) per cwt. in 1938. The exports rose from 177,664 cwts., valued at Rs. 91,76,511 (£689,963) in 1936 to 297,343 cwts., valued at Rs. 1,43,60,036 (£1,079,702) in 1937, but fell again to 175,109 cwts. valued at Rs. 1,13,25,346 (£845,175) in 1938.

TABLE 36.—*Quantity and value of Mica produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13-3).		Quantity.	Value. £ (Rs. 13-4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
Bihar—						
Bhagalpur	922	6,046	500	118	1,808	135
Gaya	20,055	7,32,788	55,097	14,700	6,46,890	48,275
Hazaribagh	61,108	23,32,718	175,392	65,371	26,71,947	199,399
Manbhum	246	7,178	540	319	8,919	666
Monghyr	3,647*	91,603	6,888	3,727	82,751	6,175
Gwalior	12	(*a*)	..	280	(*a*)	..
Madras including Madras State—						
Nilgiris	120	16,017	1,204	76	15,488	1,156
Nellore	(*b*)15,647	6,48,075	48,727	(*c*)22,201	5,81,921	43,427
Salem	..	..	..	638	10,838	809
Travancore State	67	2,150	162	240	19,002	1,425
Mysore	20	600	45	600	2,895	216
Rajputana—						
Ajmer-Merwara	(*d*)2,034	87,513	6,580	(*e*)1,684	68,926	5,144
Jaipur State	780	24,993	1,879	405	9,303	694
Tonk State	..	..	..	12,810	83,855	6,258
TOTAL	**104,658**	*39,50,281*	*297,014*	**123,169**	*42,04,633*	**313,779**

* Revised.
(*a*) Not reported.
(*b*) Excludes 28,119 cwts. of waste mica useful for splittings.
(*c*) Excludes 35,556 cwts. of waste mica useful for splittings.
(*d*) Excludes 663 cwts. of waste mica useful for splittings.
(*e*) Excludes 1,419 cwts. of waste mica useful for splittings.

TABLE 37.—*Quantity and value of Mica including Splittings exported from India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value (£ Rs. 13-3).		Quantity.	Value (£ Rs. 13-4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom	65,784	64,93,335	488,221	53,600	46,47,477	346,827
Germany	18,854	10,79,055	81,132	30,831	17,17,986	128,208
France	2,698	2,06,555	15,531	2,905	1,86,939	13,951
Japan	11,815	12,55,366	94,388	22,298	21,18,001	158,050
United States of America	185,143	43,67,799	328,406	49,445	13,56,311	101,217
Other countries	13,049	9,57,926	72,024	15,940	12,98,632	96,913
TOTAL	**297,343**	*1,43,60,036*	*1,079,702*	**175,109**	*1,13,25,346*	*845,175*

Monazite.

In its early years the monazite industry of Travancore State was of some importance and the output during the quinquennium 1914-1918 averaged annually 1,528 tons valued at £45,334. This prosperity continued only to 1921 and by 1925 the industry was moribund, with a production of 1 cwt. only. There has since been a revival and the output for the period 1929-1933 average annually 215 tons valued at £2,114. In 1934 the output was 1,009 tons valued at £3,769, which rose to 3,819 tons valued at £12,453 in 1935 but fell again to 2,628 tons valued at £8,116 in 1936, rising to 3,081 tons valued at Rs. 1,40,365 (£10,554) in 1937 and 5,221 tons valued at Rs. 2,33,700 (£17,440) in 1938.

The earlier decline of the industry from the high figures of 1914 to 1921 is believed to be due to the supplanting of incandescent mantles for gas lighting by electricity. The partial revival of the monazite industry is presumably due to the greatly increased output of ilmenite, the production of monazite as a bye-product rendering cheaper production possible. In 1938 the exports were 4,136 tons as against 3,757 tons exported in 1937, 1,936 tons in 1936 and 3,954 tons in 1935.

Nickel.

As a bye-product in the smelting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel-speiss, which, during the quinquennium 1929-1933 average annually 3,211 tons valued at

Rs. 8,19,023 (£61,197). In 1933 the output was 3,350 tons, valued at Rs. 10,28,523 (£77,333), which rose in 1934 to 3,951 tons valued at Rs. 11,44,337 (£86,401) and in 1935 to 4,850 tons, valued at Rs. 14,00,074 (£105,269). In 1936 the output was 4,325 tons valued at Rs. 14,82,809 (£111,489), in 1937 it was 4,020 tons valued at Rs. 13,91,049 (£104,590) and in 1938 the output fell to 3,015 tons valued at Rs. 11,06,323 (£82,561).

In 1938 the composition of the nickel-speiss was 31·32 per cent. of nickel, 8·60 per cent. of copper, 6·69 per cent. of cobalt, and 15·13 ozs. of silver to the ton. The speiss is believed to have been shipped to Hamburg for further treatment as usual.

Ochre.

There was a decrease in the reported production of ochre from 6,536 tons valued at Rs. 28,193 (£2,120) in 1937 to 5,616 tons valued at Rs. 28,865 (£2,154) in 1938. Central India was again mainly responsible for this decrease.

TABLE 38.—*Quantity and value of Ochre produced in India.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons	Rs.	£	Tons	Rs.	£
Central India	2,270	10,631	799	1,410	11,092	828
Central Provinces	2,455	7,195	541	2,924	9,311	695
Eastern States Agency	..	..	..	17	69	5
Gwalior	559	4,109	332	609	3,857	288
Madras (including Madras States)	724	3,795	285	272	2,558	191
Orissa	125	946	71	79	874	65
Rajputana	403	1,217	92	305	1,104	82
TOTAL	**6,536**	*28,193*	*2,120*	**5,616**	*28,865*	*2,154*

Petroleum.

The world's production of petroleum in 1937 amounted to nearly 275 million long tons, of which India contributed 0·10 per cent. and Burma 0·40 per cent. In 1938, the figure fell to some 267 million long tons, of which the Indian proportion remained at 0·10 per cent. and Burma at 0·40 per cent. The United States contributed 60·7 per cent. of the world's supply in 1938, the U. S. S. R. 10·7 per cent., Venezuela 10·4 per cent., Iran 3·7 per cent., Netherlands Indies 2·6 per cent. and Roumania 2·4 per cent. The posi-

tion of Burma on the list of petroleum producers is now 14th following Bahrein.

Production.

The production of petroleum in India (including Burma) increased from 334,811,624 gallons in 1936 to 350,322,222 gallons in 1937, the highest figure in the history of the Industry. The separate outputs of Burma and India in 1937 were 274,664,365 gallons valued at Rs. 5,95,06,155 (£4,474,147) and 75,657,857 gallons valued at Rs. 1,37,06,864 (£1,030,591) respectively. The corresponding figures for the year under review, 1938, were 263,823,265 gallons valued at Rs. 5,04,75,254 (£3,766,810) and 87,082,371 gallons valued at Rs. 1,65,43,142 (£1,234,563), respectively, which is a slight increase in total quantities but a fall in value for the combined outputs of Burma and India. The appreciable increase from India in 1938 is due to an increase of over 11 million gallons from Attock and a little from Digboi, while the decrease from Burma is due to a fall of nearly 9 million gallons from Yenangyaung, over 3 million gallons from Yenangyat (and Lanywa) and half a million gallons from Minbu (See Table 39).

The amount of gasolene produced from natural gas during the year 1938 was 10,587,291 gallons in Burma and 496,163 gallons in the Punjab.

Burma fields.

The Yanangyaung field maintained its reputation of being one of the most wonderful oilfields in the world. The total production during 1938 was less than in the previous year, but the resources of the field as a whole are sufficient to ensure an adequate supply of oil for many years.

At the end of 1938 there were 2,905 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 195 hand-dug wells, whose continued existence is one of the interesting features of the field.

There were no important discoveries of new producing horizons during the year under review. Satisfactory results continue to be obtained from gas drives in the leased blocks; in addition to gas drives, gas is also injected with the object of repressuring and storage. Casing policies continue to be carefully designed to protect the oil-sands against the danger of flooding by water and, in general, production methods throughout the field are characterised by a realisation of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

In 1938 the increase in the output from the Singu field was continued. This increased production was due not only to the rapid development of the valuable area in the southern part of the field but also the successful results obtained from the first wells to produce from behind the practically completed river training wall of the Burmah Oil Company. At the end of the year the total number of producing wells was 562 as compared with 568 in December, 1937. In addition, a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

There has been no radical change in production methods during the year under report. The fundamental principle underlying the policy of the major operating company at Singu is to make those adjustments at each well which lead to a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the balance of casing-head gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. The repressuring operations of the British Burmah Petroleum Company, Ltd., continued to give satisfactory results. The dry gas produced from the new gasoline extraction plant is used either in connection with these schemes or as fuel.

Continuous gas lift on some wells producing from lower division sands and gas displacement pumping on wells producing from upper division sands were continued on a small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

Although, during 1938, active development continued at Yenangyat, the results obtained were somewhat disappointing and a decline in the total production from the Pakokku district, excluding Lanywa, was reported. As compared with 1937, there was little change in the production from the Lanywa field during 1938. The successful application of directional drilling methods in order to tap the known oil sands beneath the Irrawaddy river has greatly improved the prospects of the Lanywa field. Back pressures are maintained on nearly all the wells in this model field, which is operated by the Indo-Burma Petroleum Company, Ltd. While a number of wells are pumped from a central power, the majority

have individual pumping motors. The gasoline plant was operated throughout the year and gave a satisfactory yield.

In the Minbu district there were, at the close of the year, 318 producing wells. There was a further decrease in total production and apart from routine production there was very little activity in the district during the year.

There was a slight decrease during 1938 in the total production from the Indaw field. With the exception of four wells at the northern end of the field, all producing wells were successfully operated by the automatic gas lift system.

In the Thayetmyo district, whilst there was a slight decrease in production in the Padaukpin field, that of the Yenanma field showed a further considerable increase. An extension of the known producing area was proved in this field. The supply of natural gas from the Pyaye field for use as fuel in the Burma Cement Company's factory was maintained during 1938.

The output from Kyaukpyu remained at its usual low level.

Assam.

In Assam output of the Digboi field increaseds lightly. Shallow drilling has been carried out in the Kharjam Mining Lease to investigate the structure in the wide area where the rocks are hidden beneath the alluvium, and drilling to test the prospects of obtaining oil in the Namdang Mining Lease is in progress. Preparations are advanced for drilling borings to obtain geological information from beneath the alluvium gravels in the Namphuk prospecting licence area.

Geophysical and geological work has been carried out to elucidate the structure in the area covered by the Tiru Hills prospecting licence, and that information boring will be necessary here also before the prospects of finding oil at depth can be evaluated.

Geophysical surveying, using both gravity and seismic methods, has been carried out over a large portion of the Assam Valley, in an attempt to discover whether any structure suitable for the concentration and retention of oil occur hidden below the blanket of alluvium which occupies this valley. This work was still in progress at the end of the year.

In the Surma Valley there was no production. The seismic work at Masimpur gave no help in elucidating the structural complications, and core drilling was started to obtain geological information from considerable depth: one of these core holes has since reached objective at 5,000 feet. A further large programme of

shallow information boring to trace the rock boundaries where obscured by alluvium, and thus further to elucidate the details of the structure, was initiated during the year and is in progress.

Geological mapping has been carried out in the Olahtaung Concession on the Arakan Coast, and in the area covered by the Sylhet prospecting licence; and an air survey of Tripura State has been made preparatory to detailed geological work on the ground.

In the Sitakund Concession preparations had been completed to undertake an extensive programme of shallow drilling to obtain geological information regarding the structure on the western flank, and at the end of the year drilling was about to start.

Punjab.

In the Punjab the Attock Oil Co., Ltd., operated the Khaur and Dhulian Fields and also carried out tests at Ganda Kas and Jhatia outfields.

In the Khaur Field the deep test referred to in last year's report was a disappointment—producing 4/5 barrels only of oil daily along with a considerable quantity of water. This, it appears, will continue for some time to come.

No further deep or shallow drilling was undertaken at this field and production was restricted by producing only from wells where conditions are unsuitable for closing down.

In the Dhulian Field developments have continued to be satisfactory. The two wells reported as producing 480 and 640 barrels of oil per day respectively were mudded off pending the erection of the new Refinery. Two more wells wêre drilled into the 7,500/7,700 feet horizon and gave initial productions of 2,200 barrels and 3,000 barrels daily respectively. Both these wells were beaned down to an aggregate of about 1,700 barrels daily, partly to suit Refinery requirements and storage facilities and partly in the interests of economical recovery of production. A further three wells were drilled and cemented above the main oil horizon, while a further development well has been stopped temporarily at 6,470 feet.

At Ganda Kas, about 30 miles North-West of Khaur, a test well was carried down to 1,775 feet but has since been abandoned owing to structural complications. It has been decided a second test well and drilling operations are now in progress.

A test well at Jhatla about 30 miles South of Khaur was drilled and carried down to 3,758 feet at the end of the year. It is now being deepened further and may require to be taken down to 7,000 feet or deeper.

TABLE 39.—*Quantity and value of Petroleum produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
India—						
Assam—						
Digboi	65,718,437	1,12,22,009	843,760	65,968,951	1,12,64,787	840,656
Punjab—						
Attock	9,939,420	24,84,855	186,831	21,113,420	52,78,355	393,907
TOTAL	**75,657,857**	*1,37,06,864*	*1,030,591*	**87,082,371**	*1,65,43,142*	*1,234,563*
Burma—						
Kyaukpyu	12,437			11,189		
Minbu	3,418,311			2,929,940		
Singu	119,858,608			120,709,811		
Thayetmyo	2,001,180	5,95,06,155 (*a*)	4,474,147	2,712,800	5,04,75,254	3,766,810
Upper Chindwin	2,502,140			2,359,568		
Yenangyat (including Lanywa).	25,067,655			22,022,443		
Yenangyaung	121,804,034			113,017,514		
TOTAL	**274,664,365**	*5,95,06,155*	*4,474,147*	**263,823,265**	*5,04,75,254*	*3,766,810*

(*a*) Estimated.

TABLE 40.—*Imports of Kerosene Oil into India.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
U. S. S. R.	27,377,419	91,29,184	686,405	3,629,596	11,72,058	87,467
Iran	8,218,665	30,27,007	227,595	26,507,700	91,24,795	680,955
Burma	93,466,680	3,77,72,485	2,840,037	126,671,677	4,77,04,125	3,560,009
Sumatra	27,955,437	86,05,758	647,049	8,264,220	32,53,543	242,802
Borneo (Dutch)	..	..	..	10,892,243	37,92,107	283,000
U. S. A.	3,011,333	6,50,429	48,904	1,006,940	2,86,591	21,387
Other Countries	2,815,014	8,87,267	66,712	11,472,364	37,80,892	282,156
TOTAL	**162,844,548**	*6,00,72,130*	*4,516,702*	**188,444,740**	*6,91,14,201*	*5,157,776*

TABLE 41.—*Imports of Fuel oil into India.*

	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4)	
	Gals.	Rs.		Gals.	Rs.	£
From—						
U. S. S. R.				2,381,494	5,40,660	40,348
Iran	97,611,519	1,28,16,934	963,679	98,724,489	1,22,03,726	910,726
Burma*	1,099,122	3,12,422	23,490	[illegible],439,328	7,83,483	58,469
Straits Settlements	10,108,149	15,67,421	117,851	1,719,983	3,12,730	23,338
Borneo (British)	13,050,640	26,67,882	[illegible]	13,445,351	25,29,899	188,798
Borneo (Netherlands)	5,426,441	9,81,040	73,762	12,382,1[illegible]5	23,36,000	174,328
Other Countries	513,185	1,12,246	8,440	4,094,020	7,13,912	53,277
TOTAL	**127,809,056**	*1,84,57,945*	*1,387,815*	**135,216,770**	*1,94,20,410*	*1,449,284*

* From 1st April, 1937.

TABLE 42.—*Exports of Paraffin Wax from India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons	Rs.	£	Tons	Rs.	£
To—						
United Kingdom	9,422	42,00,674	315,840	3,994	19,10,350	142,563
Germany	..	..	..	887	3,10,346	23,160
Netherlands	994	4,18,304	31,451	155	75,950	5,668
Belgium	974	4,10,568	30,870	240	1,17,600	8,776
Italy	860	3,61,305	27,166	..	..	..
China	2,111	6,96,035	52,333	800	2,80,000	20,896
Union of South Africa	1,903	7,29,616	54,858	695	2,43,250	18,153
Portuguese East Africa	2,085	8,04,554	60,493	2,098	7,34,100	54,784
Canada	835	3,50,700	26,368	..	..	..
U. S. A.	755	3,20,600	24,105	25	12,250	914
Mexico	2,400	11,84,579	89,066	400	1,96,000	14,627
Columbia	1,254	5,26,523	39,588	..	..	..
Chile	650	2,73,000	20,526	..	..	..
Australia	127	53,340	4,011	..	..	..
Other Countries	1,294	5,72,376	43,036	14	4,805	358
TOTAL	**25,673**	*1,09,02,174*	*819,711*	**9,308**	*38,84,651*	*289,899*

Ruby, Sapphire and Spinel.

After the liquidation of the Burma Ruby Mines, Limited, and the final cessation of the operations of this company in 1931, there was an interval during which reliable statistics of production of gem-stones in the Mogok Stone Tract were unobtainable. Work, however, is still continued by local miners; in addition a certain amount of work is being done under extraordinary licenses. For 1932 no returns were available, except that a fine ruby of 17 carats, a fine sapphire of about 90 carats and a good star sapphire of 453 carats were mined. For 1933 the only return was of 1,103 carats of rubies. For 1934, however, there was a reported production of 21,622 carats of rubies valued at Rs. 36,011 (£2,708) and 153 carats of sapphires valued at Rs. 330 (£25).

In 1935 there was an output of 98,753 carats of rubies valued at Rs. 1,10,213 (£8,287), 202 carats of sapphires valued at Rs. 329 (£25) and 6,687 carats of spinels valued at Rs. 3,850 (£289). In 1936 the production was 155,381 carats of rubies valued at Rs. 97,103 (£7,301), and 172 carats of sapphires valued at Rs. 242 (£18), and in 1937, 157,308 carats of rubies, valued at Rs. 90,990 (£6,841) and 4,392 carats of sapphires, valued at Rs. 3,035 (£228). For 1938 the returns are shown in the Table 43 where a very marked increase in both rubies and sapphires from Burma is made clear.

In addition, the production was reported from Soomjam in the Padar district of Kashmir State in 1937, of 18,344 carats of sapphire, valued at Rs. 550 (£41) and 4,892 carats of sapphire valued at only Rs. 150 (£11) in 1938. (See also Corundum, p. 308.) The sapphire deposits of Kashmir have long been known, but on account of their high altitude they are worked only occasionally.

TABLE 43.—*Quantity and value of Ruby and Sapphire produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Carats.	Rs.	£	Carats.	Rs.	£
India—						
Kashmir State . .	18,344 (Sapphire).	550	41	4,892 (Sapphire).	150	11
Burma—						
Katha	157,308 (Ruby)	90,990	6,841	202,483 (Ruby)	1,07,919	8,054
	4,392 (Sapphire)	3,035	228	10,344 (Sapphire)	39,557	2,952
TOTAL .	**161,700**	***94,025***	***7,069***	**212,827**	***1,47,476***	***11,006***

Salt.

There was a moderate increase in the production of salt in India in 1938 made up of increases in the production in Northern India and Madras, with decreases in the production in Sind and Bombay. The production in Aden was less in 1938 than in 1937; the production in Burma showed a large decrease.

There was a decrease in the imports of salt into India in 1938. The quantity of rock-salt produced in India in 1938 was slightly more than in 1937.

TABLE 44.—*Quantity and value of Salt produced in India, Aden and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons.	Rs.	£	Tons	Rs.	£
India—						
Bengal	112	7,865	591	267	3,595	268
Bombay	489,742	22,86,482	171,916	406,992	18,84,939	140,667
Gwalior (*a*)	55	2,680	202	183	9,711	725
Madras	421,014	20,87,038	156,920	453,954	31,00.561	231,385
Northern India	465,712	31,74,484	238,683	582,391	40,36,224	301,211
Sind	116,386	5,88,816	44,272	95,876	4,83,353	36,071
TOTAL	**1,493,021**	*81,47,365*	*612,584*	**1,539,603**	*95,18,383*	*710,327*
Aden	355,166	(*b*)20,70,618	155,686	278,047	(*b*)16,24,014	120,971
Burma	53,813	(*b*)8,24,953	62,026	38,698	(*b*)5,94,014	44,329

(*a*) Figures relate to official years 1937-38 and 1938-39.
(*b*) Estimated.

TABLE 45.—*Quantity and value of Rock-Salt produced in India.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Salt Range	162,192	11,71,837	88,108	163,723	11,82,899	88,276
Kohat	20,855	64,187	4,826	20,698	62,810	4,687
Mandi	4,053	1,09,764	8,253	3,951	1,06,622	7,957
TOTAL	**187,100**	*13,45,788*	*101,187*	**188,372**	*13,52,331*	*1,00,920*

TABLE 46.—*Imports of Salt into India.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
Germany	41,577	6,69,468	50,336	27,752	4,52,781	33,789
Aden and Dependencies	295,879	52,80,684	397,044	216,883	26,97,967	201,341
Egypt	1,000	15,269	1,148	61,209	6,62,123	49,412
Other Countries	530	97,489	7,330	26,111	3,86,867	28,871
TOTAL	**338,986**	*60,62,910*	*455,858*	**331,955**	*41,99,738*	*313,413*

Saltpetre.

Although complete statistics of production of saltpetre in India are no longer available (*see Rec. Geol. Surv. Ind.*, LXIV, p. 289), yet the export figures may be accepted as a fairly reliable index to the general state of the industry, for, excepting a few hundreds of tons required for internal consumption as fertiliser, most of the output is exported to foreign countries. The quantity exported increased from 167,147 cwts. valued at Rs. 11,17,844 (£84,048) in 1937 to 148,824 cwts. valued at Rs. 11,68,446 (£87,197) in 1938. Nevertheless, figures of production of refined saltpetre—without values—are available for tracts worked under the supervision of the Northern India Salt Revenue Department. The production figures for the financial years 1936-37, 1937-38 and 1938-39 are:—

	1936-37.	1937-38.	1938-39.
	Tons.	Tons.	Tons.
Bihar . .	1,004	963	1,324
Punjab .	8,566	5,788	5,109
United Provinces	1,648	1,881	2,275
TOTAL	11,218	8,632	8,708

A certain amount of nitrate of potash, is used for agricultural purposes on the tea gardens of India. During the War of 1914-18, when it was impossible to obtain supplies of imported potash, the amount of locally produced nitrate utilised in this way reached an appreciable figure. The practice continued and the quantity estimated to have been absorbed for fertilising purposes on tea gardens was 600 tons in 1936, 500 tons in 1937 and 300 tons in 1938.

TABLE 47.—*Distribution of Saltpetre exported from India during the years 1937 and 1938.*

	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom	37,251	2,80,861	21,117	20,951	2,04,300	15,246
Ceylon . .	21,886	1,22,405	9,203	18,431	1,17,716	8,785
Mauritius and Dependencies	77,983	4,83,891	36,383	78,760	5,98,178	44,640
Other Countries .	30,027	2,30,687	17,345	30,682	2,48,252	18,526
TOTAL	**167,147**	*11,17,844*	*84,048*	**148,824**	*11,68,446*	*87,197*

Silver.

The production of silver from the Bawdwin mines of the Burma Corporation, Limited, during 1938 decreased by 269,000 ozs. as compared with 1937, accompanied by a fall in value of Rs. 4,77,814 (£39,788) (*see* Table 48 and Lead, p. 319).

The output of silver obtained as a bye-product from the Kolar gold mines of Mysore showed a fall of 2,347 ozs.

The amount of silver bullion and coin exported during the year was 8,817,822 ozs. valued at Rs. 1,25,49,663 (£936,542) as compared with 5,311,827 ozs. valued at Rs. 1,09,93,186 (£826,555) in 1937 and 2,763,274 ozs. valued at Rs. 34,30,310 (£257,918), during 1936.

TABLE 48.—*Quantity and value of Silver produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Ozs.	Rs.	£	Ozs.	Rs.	£
India—						
Mysore State	24,642	32,343	2,432	22,295	29,877	2,230
Burma—						
Northern Shan States . .	6.180,000	73,60,998	553,458	5,920,000	68,83,184	513,670

Soda.

The output of soda (*phulli*) in Kashmir State was 7 tons valued at Rs. 194 (£15) in 1934; the production in 1935 and 1937, was *nil*, and 1 ton, valued at Rs. 33 (£2) in 1936. No production figure for 1938 is yet available.

Steatite.

There was an increase in the production of steatite from 13,040 tons, valued at Rs. 1,55,221 (£11,671) in 1937 to 18,590 tons valued at Rs. 1,68,580 (£12,581) in 1938. The increased production came principally from Guntur (Madras), Jubbulpore remaining almost stationery, and Jaipur State and Hazaribagh falling, these being the principal sources.

TABLE 49.—*Quantity and value of Steatite produced in India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4)	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar—						
Hazaribagh	918	5,678	427	618	3,708	277
Singhbhum	82	287	22	74	277	21
Central India—						
Bijawar State	55	1,220	92	90	1,980	148
Central Provinces—						
Bhandara	253	190	14	245	818	61
Jubbulpore	1,858	9,390	706	1,944	5,551	413
Eastern States Agency—						
Mayurbhanj State	68	6,552	493	70	6,696	500
Seraikela State	153	5,239	394	88	3,458	258
Madras—						
Anantapur	13	195	15	..	..	..
Guntur	..	..	..	7,128	4,755	354
Nellore	27	1,080	81	82	1,280	95
Salem	268	3,365	253	408	5,476	410
Mysore State	90	601	45	76	527	39
Rajputana—						
Alwar State	106	724	54	..	..	..
Jaipur State	9,041	1,20,000	9,023	7,758	1,33,340	9,951
United Provinces—						
Hamirpur	106	550	41	39	250	19
Jhansi	7	150	11	20	469	35
TOTAL	**13,040**	*1,55,221*	*11,671*	**18,590**	*1,68,580*	*12,581*

Sulphate of ammonia.

Until recently, figures of production of ammonium sulphate as a bye-product at the coking plants of iron and steel works and collieries have been collected only every five years for the Quinquennial Reviews of Mineral Production. They prove, however, to be of such general interest that it has been thought desirable to report them annually, and the figures for 1937 and 1938 are shown in Table 50. Values have not been obtained, and ammonium sulphate does not therefore find a place in Table 1. The figures show an important decrease in production from 18,150 tons in 1937 to 14,616 tons in 1938. The exports for 1938 and 1937 were 1,313 and 1,919 tons, respectively.

TABLE 50.—*Production of Sulphate of Ammonia in India during the years 1937 and 1938.*

——	1937.	1938.
	Tons.	Tons.
The Tata Iron and Steel Company, Limited .	6,474	7,863
The Indian Iron and Steel Company, Limited .	8,673	3,807
The Burrakur Coal Company, Limited . .	1,135	1,191
State Railways Coal Department, Giridih . .	532	449
The Bararee Coke Company, Limited . .	1,336	1,306
TOTAL .	18,150	14,616

Tantalite.

11·2 cwts. of tantalite valued at Rs. 301 (£23) were produced in the Monghyr district of Bihar during 1937. There was no production in 1938.

Tin Concentrates.

A further increase is recorded in the production of tin concentrates from Burma, including Karenni State, from 6,494·8 tons valued at Rs. 1,03,83,166 (£780,689) in 1936, to 6,622·5 tons valued at Rs. 1,09,59,215 (£824,001) in 1937. This is the highest quantity yet recorded in any one year. The production in 1938 was, however, 6,303 tons valued at Rs. 78,93,160 (£589,042). There was no reported output of block tin.

Imports of unwrought tin rose from 46,084 cwts. valued at Rs. 62,72,482 (£471,615) in 1936 to 51,489 cwts. valued at Rs. 79,65,610 (£598,918) in 1937, and to 56,891 cwts. valued at Rs. 70,72,214 (£527,777); 90·4 per cent. of these imports came from the Straits Settlements.

TABLE 51.—*Quantity and value of Tin concentrates produced in Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Amherst	36·4	67,233	5,055	37	54,069	4,035
Mergui	1,694·5	29,49,155	221,741	1,889	29,89,373	223,088
Tavoy	2,919·8	47,53,262	357,388	2,550	25,72,321	191,964
Thaton	4·9	6,720	505	3	4,362	326
Yamethin	55·1	97,200	7,308	(*a*) 39	36,651	2,735
Mong Pai State	..	..	..	1	2,370	177
Karenni State	1,911·8	(*b*)30,85,645	232,004	1,784	(*b*)22,34,014	166,717
TOTAL	6,622·5	*1,09,59,215*	*824,001*	6,303	*78,93,160*	*589,042*

(*a*) Excludes 58 tons of mixed tin and wolfram concentrates, the composition of which is not known.
(*b*) Estimated.

TABLE 52.—*Imports of Unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
From—						
United Kingdom	1,057	1,75,919	13,227	233	30,865	2,303
Burma*	3,521	3,39,003	25,489	4,937	4,89,318	36,516
Straits Settlements	46,708	74,28,957	558,568	51,470	65,18,216	486,434
Other countries	203	21,731	1,634	251	33,815	2,524
TOTAL	51,489	*79,65,610*	*598,918*	56,891	*70,72,214*	*527,777*

* From 1st April, 1937.

Tungsten-ore (Wolfram).

An important increase in quantity and a little in the total value of the output of wolfram from Burma has to be recorded, namely from 4,997·7 tons valued at Rs. 80,22,748 (£603,214) in 1937 to 5,343·0 tons valued at Rs. 81,39,488 (£607,424) in 1938. The price per unit fell from 79·5 shillings in January 1938 to 39 shillings in May and gradually rose to 62·5 shillings in October but fell again in December to 52·0 shillings. The average price was 58·42 shillings per unit.

TABLE 53.—*Quantity and value of Tungsten concentrates produced in India and Burma during the years 1937 and 1938.*

—	1937.			1938.		
	Quantity.	Value £ (Rs. 13·3).		Quantity.	Value £ (Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
India—						
Jodhpur State	13·0	24,500	1,842	10	0,600	716
Burma—						
Amherst	0·5	480	36	1·0	1,570	117
Mergui	276·9	3,31,200	24,902	298·0	3,24,156	24,191
Tavoy	2,760·2	45,08,034	338,950	3,057·0	48,70,674	363,483
Thaton	58·7	92,736	6,973	97·0	1,14,981	8,581
Yamethin	252·0	4,71,759	35,471	394·0	5,47,461	40,855
Mong Pai State	..	..	..	2·0	4,730	353
Karenni State	1,649·4	(a)26,18,539	196,882	1,494·0	(a) 22,75,916	169,844
TOTAL	**4,997·7**	*80,22,748*	*603,214*	**5,343·0**	*81,39,488*	*607,424*

(a) Estimated.

Zinc.

The production of zinc concentrates by the Burma Corporation Limited, in the Northern Shan States, fell from 73,552 tons valued at Rs. 54,40,421 (£409,054) in 1937 to 60,744 tons valued at Rs. 30,77,959 (£229,698) with depreciated price. The exports during the year under review amounted to 64,651 tons valued at Rs. 29,31,955 (£218,803) as against 82,686 tons, valued at Rs. 54,95,366 (£413,185) in 1937.

Zinckenite.

About 31 tons of zinckenite are reported to have been obtained from the mines at Shogar in Chitral State since exploration began in this locality about two years ago. No value of this ore has been yet determined. The mineral zinckenite is an antimony lead sulphide normally averaging 41·8 per cent. antomony, 35·9 per cent. lead and 22·3 per cent. sulphur when pure. (*See* Antimony).

Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, increased from 1,329 tons valued at Rs. 39,036 (£2,935) in 1937 to 1,450 tons valued at Rs. 40,737 (£3,040) in 1938. The exports rose to 1,727 tons in 1938 as against 1,037 tons in 1937.

III.—MINERAL CONCESSIONS GRANTED.

TABLE 54.—*Statement of Mineral Concessions granted during the year 1938.*

AJMER-MERWARA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Ajmer	(1) L. Prag Narain	Felspar	P. L. (Renewal).	1·98	30th November 1937.	1 year.
Do.	(2) L. Ladoolal Kataria	Mica and beryl	P. L. (Renewal).	0·88	15th February 1938.	Do.
Do.	(3) Mr. Abdul Ghani	Mica, beryl-ore, and felspar.	P. L. (Renewal).	8·54	15th February 1938.	Upto 21st December 1938.
Do.	(4) Do.	Do.	P. L. (Renewal).	6·46	Do.	Do.
Do.	(5) L. Prag Narain	Asbestos and kyanite.	P. L. (Renewal).	1·26	28th February 1938.	1 year.
Do.	(6) Mr. J. K. Soneji	Mica, felspar and beryl-ore.	P. L.	0·56	25th February 1938.	Do.
Do.	(7) Do.	Do.	P. L.	0·7	5th March 1938.	Do.
Do.	(8) Messrs. Shyam Beharilal Shyamsunderlal.	Mica and beryl	P. L.	4·25	27th April 1938.	Do.
Do.	(9) Kr. Goverdhanlal Rathi	Do.	P. L.	1·39	20th May 1938	Do.
Do.	(10) Mr. J. K. Soneji	Mica, felspar and beryl-ore.	P. L.	0·68	10th June 1938.	Do.
Do.	(11) L. Kanhiyalal	Mica	P. L.	9·6	31st May 1938.	Do.
Do.	(12) L. Ladoolal	Do.	P. L.	0·88	18th June 1938.	Do.
Do.	(13) J. K. Soneji	Do.	P. L.	0·24	15th July 1938	Do.
Do.	(14) Messrs. Ghisalal Sethi and Sons.	Mica and beryl unconnected with gems.	P. L.	1·33	9th August 1938.	Do.
Do.	(15) Do.	Mica	P. L.	1·6	14th October 1938.	Do.
Do.	(16) Do.	Mica and beryl ore	P. L.	2·77	20th November 1938.	Do.
Do.	(17) Do.	Do.	P. L.	3·04	Do.	Do.
Do.	(18) Messrs. Shamlal Pragnarain.	Muscovite	P. L.	1·97	10th October 1938.	Do.
Do.	(19) Messrs. Beharilal Shamsunderlal & Co.	Mica	P. L.	5·8	21st November 1938.	Do.
Do.	(20) Messrs. Seth Ghisalal Sethi & Sons.	Do.	P. L.	4·62	28th November 1938.	Do.
Do.	(21) Mr. J. K. Soneji	Mica, felspar and beryl ore (unconnected with gems).	P. L.	2·04	22nd December 1938.	Do.
Do.	(22) Messrs. Abdul Ghani & Co.	Mica, felspar and beryl.	M. L.	1 26	21st July 1938.	3 years.
Do.	(23) Mr. J. K. Soneji	Mica and muscovite	M. L.	0·65	20th July 1938	Do.
Do.	(24) Messrs. Abdul Ghani & Co.	Mica, felspar and beryl.	M. L.	7·48	29th August 1938.	Do.
Beawar	(25) P. Sunderlal Sharma.	Mica and beryl	P. L.	2·4	14th January 1938.	1 year.
Do.	(26) L. Goverdhanlal Rathi.	Mica	P. L.	1·5	17th February 1938.	Do.
Do.	(27) Mr. D. P. Mody	Do.	P. L.	5·21	12th November 1937.	Do.
Do.	(28) Do.	Do.	P. L.	7·15	17th February 1938.	Do.
Do.	(29) L. Sahib Chand Surana.	Do.	P. L.	14·21	..	
Do.	(30) Do.	Mica and beryl	P. L.	3·35	16th May 1938	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

AJMER-MERWARA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Beawar	(31) Qazi Syed Mohammed Niyaz Ali.	Mica	P. L.	14·12	28th May 1938	Upto 22nd September 1938.
Do.	(32) Mr. Sahib Chand Surana.	Do.	P. L.	14·12	23rd September 1938.	Upto 22nd January 1939.
Do.	(33) Mr. Sunderlal Sharma.	Do.	P. L.	1·6	20th July 1938	1 year.
Do.	(34) L. Kanahiyalal	Do.	P. L.	0·55	3rd August 1938.	Do.
Do.	(35) Quazi Syed Mohd. Niyaz Ali.	Do.	P. L.	1·84	24th August 1938.	Do.
Do.	(36) L. Fatehchand	Do.	P. L.	1·6	7th December 1938.	Do.
Do.	(37) Kanwar Goverdhanlal.	Do.	P. L.	7·19	19th December 1938.	Do.
Do.	(38) Messrs. Tricumdass & Co.	Do.	P. L.	139·7	10th December 1938.	Do.
Do.	(39) Quazi Syed Mohd. Niyaz Ali.	Do.	M. L.	6·56	28th May 1937	3 years.
Do.	(40) Mr. J. K. Soneji	Mica, felspar and beryl.	M. L.	3·05	27th September 1938.	Do.
Manoharpura Estate.	(41) Kr. Goverdhanlal Rathi.	Mica	M. L.	Whole of Manoharpur village.	..	

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar	(42) The Burmah Oil Co., Ltd.	Natural petroleum including natural gas.	P. L	4,788	4th July 1938	1 year.
Do.	(43) Do.	Do.	P. L	3,623	28th March 1938.	Do.
Do.	(44) Do.	Do.	P. L	6,169	6th April 1938	2 years.
Do.	(45) Do.	Do.	P. L	3,001	Do.	Do.
Do.	(46) Do.	Do.	P. L	2,060	Do.	Do.
Do.	(47) Do.	Do.	P. L	1,088	Do.	Do.
Do.	(48) Do.	Do.	P. L	5,414	Do.	Do.
Do.	(49) Do.	Do.	P. L	537	Do.	Do.
Do.	(50) Do.	Do.	P. L	4,520	Do.	Do.
Do.	(51) Do.	Do.	P. L	3,123	Do.	Do.
Lakhimpur District.	(52) Assam Oil Co., Ltd., Digboi.	Natural petroleum	M. L	5,760	1st August 1938.	30 years.
Do.	(53) Do.	Do.	P. L	5,120	30th March 1938.	1 year.
Nongstoin State.	(54) Mr. H. M. Hance, Calcutta.	Sillimanite, corundum and all associated refractory minerals.	P. L	640	14th April 1938.	1 year.
Do.	(55) Do.	Do.	P. L	480	Do.	Do.
Sylhet District.	(56) The Burmah Oil Co., Ltd.	Natural petroleum including natural gas.	P. L	3,136	6th April 1938	2 years.
Do.	(57) Do.	Do.	P. L	3,161	Do.	Do.
Do.	(58) Do.	Do.	P. L	9,305	Do.	Do

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Quetta Pishin Agency.	(59) Rai Sahib Tikamdas Girdharidass.	Coal	M. L.	80	1st January 1939.	30 years.
Do.	(60) Messrs. Rai Sahib Jawal Singh, Jagat Singh.	Do.	M. L.	80	Do.	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BALUCHISTAN—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Sibi Agency .	(61) Rai Sahib Tikamdas Girdharidas.	Coal . . .	M. L. .	80	1st July 1938	30 years.
Do. .	(62) Mullick Wilayet Hussain.	Do. . . .	M. L. .	80	Do. .	Do.
Loralai Agency.	(63) The Indo-Burma Petroleum Co., Ltd.	Natural petroleum including natural gas.	P. L. .	5,760 approximately.	19th November 1938.	1 year.

BIHAR.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh .	(64) Rai Bahadur S. K. Sahana.	Mica . . .	M. L. .	40	*	
Do. .	(65) Babu Ramji Valji.	Do. . . .	M. L. .	40	*	
Do. .	(66) Messrs. Lakshmi Narayan Ram Narayan.	Do. . . .	M. L. .	120	(a)	
Do. .	(67) Khan Bahadur M. A. Momin, C.I.E., M.L.C.	Do. . . .	M. L. .	140·14	*	
Do. .	(68) Babu Madan Lal Bagaria.	Do. . . .	M. L. .	40	*	
Santal Parganas.	(69) Babu Varjang Harji.	Manganese ore .	P. L. .	207·20	23rd December 1938.	1 year.
Do. .	(70) Do. .	Do. . .	P. L. .	725·00	Do. .	Do.
Do. .	(71) Mr. Bibhuti Bhushan Mitra.	Do. . .	P. L. .	68,00	Do. .	Do.
Do. .	(72) Babu Madan Gopal Rungta.	Do. . .	P. L. .	279·50	Not executed.	Do.
Do. .	(73) Babu Sushil Kumar Vanjo.	Do. . .	P. L. .	218·60	Do. .	Do.
Do. .	(74) Mr. S. Lal . .	Do. . .	P. L. .	1,086·60	Do. .	Do.
Do. .	(75) Babu Madan Gopal Rungta.	Do. . .	P. L. .	270·00	Do. .	Do.
Do. .	(76) Babu Vajang Harji.	Do. . .	P. L. .	761·50	Do. .	Do.
Do. .	(77) Babu Sushil Kumar Vanjo.	Do. . .	M. L. .	23·00	Do. .	5 years.
Do. .	(78) Babu Sreegopal Bazar	Do. . .	M. L. .	65·50	Do. .	10 years.
Do. .	(79) Babu Narendra Nath Kumar.	Do. . .	M. L. .	15·38	Do. .	Will terminate on 24th March 1945 with option of renewal.
Do. .	(80) Rai Bahadur Ratanlal Surajmal.	Chromite . .	P. L. .	68·00	Do. .	1 year.
Do. .	(81) Babu Bhagwan Das Thakur.	Do. . .	P. L. .	92·80	23rd December 1938.	Do.
Do. .	(82) Babu Mangilal Rungta.	Do. . .	P. L. .	599·50	Not executed.	Do.
Do. .	(83) Mr. Bibhuti Bhushan Mitra.	Do. . .	P. L. .	460·00	Do. .	Do.
Do. .	(84) Babu Subodh Chandra Do.	Coal . . .	M. L. .	5	1st January 1938.	2 years.
Do. .	(85) Babu Rameshwar Marwari Darji.	Do. . . .	M. L. .	5	1st October 1938.	Do.
Do. .	(86) Babu Ganga Ram Marwari.	Do. . . .	M. L. .	4·92	1st November 1938.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

* Possession given on an undertaking given to execute a lease on the terms laid down in the Revenue Department letter no. 6889-R., dated the 1st August 1938,' *i.e.*, the lessee should pay dead rent at the rate of Rs. 12 per acre until the revised rate for the same is finally approved by Government.

(a) Deputy Commissioner has been asked to give possession on their giving an undertaking as above.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(87) The Hon'ble Mr. Narayan das Girdhardas of Madras.	Bauxite . . .	P. L. .	36·55	8th June 1938.	1 year.
Do. .	(88) Do. .	Do. . .	P. L. .	58·2	Do. .	Do.
Do. .	(89) Do. .	Do. . .	P. L. .	27·17	Do. .	Do.
Do. .	(90) Do. . .	Do. . .	P. L. .	9·55	Do. .	Do.
Do. .	(91) Do. .	Do. . .	P. L. .	116·32	Do. .	Do.
Do. .	(92) Do. .	Do. . .	P. L. .	260·00	Do. .	Do.
Do. .	(93) Do. .	Do. . .	P. L. .	24·97	Do. .	Do.
Do. .	(94) Do. .	Do. . .	P. L. .	212·65	20th June 1938.	Do.
Do. .	(95) Do. .	Do. . .	P. L. .	45·67	8th August 1938.	Do.
Do. .	(96) Do. .	Do. . .	P. L. .	69·05	Do. .	Do.
Do. .	(97) Do. .	Do. . .	P. L. .	114·57	Do. .	Do.
Do. .	(98) Do. .	Do. . .	P. L. .	61·4	28th May 1938.	Do.
Do. .	(99) Do. .	Do. . .	P. L. .	7·25	Do. .	Do.
Do. .	(100) Do. .	Do. . .	P. L. .	4·65	Do. .	Do.
Do. .	(101) Mr. Gulamhusein Chhaganbhai Momin of Bombay.	China clay . .	P. L. .	13·97	2nd November 1938.	Do.
Broach and Panch Mahals.	(102) The Presidency of Bombay Researching Syndicate.	Gold and silver	M. L. .	3,356·57	5th December 1938.	30 years.
Kanara .	(103) Messrs. Killick Nixon & Co., Bombay.	Manganese-ore .	M. L. .	203·6	License not yet executed.	For the period ending 30th September, 1944.
Do. .	(104) Do. .	Do. . . .	M. L. .	290	Do. .	10 years.
Do. .	(105) Mr. R. F. Nariman	Do. . . .	M. L. .	642	Do. .	Do.
Do. .	(106) The Hon'ble Mr. Narayan Das Girdhardas of Madras.	Do. . . .	M. L. .	345·6	Do. .	Do.
Do. .	(107) Mr. Lalbhai P. Patel.	Do. . . .	M. L. .	620	Do. .	Do.
Do. .	(108) Do. .	Do. . . .	P. L. .	264	8th February 1938.	1 year.
Do. .	(109) Do. .	Do. . . .	P. L. .	170	22nd January 1938.	Do.
Do. .	(110) Do. .	Do. . . .	P. L. .	1,010	Do. .	Do.
Do. .	(111) Do. .	Do. . . .	P. L. .	620	Do. .	Do.
Do. .	(112) Messrs. D. M. Lilve & Sons of Bombay.	Do. . . .	P. L. .	208	12th August 1938.	Do.
Do. .	(113) Messrs. Oakley Duncan & Co., of Bangalore.	Do. . . .	P. L. .	827·15	12th March 1938.	Do.
Bombay Suburban.	(114) The Associated Cement Cos., Ltd.	Limestone, clay and gypsum.	P. L. .	4,775·3	28th October 1938.	Do.

CENTRAL PROVINCES AND BERAR.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(115) Messrs. B. Bose & Co., 20, Strand Road, Calcutta.	Manganese-ore .	P. L. .	94	10th January 1938.	1 year.
Do. .	(116) Messrs. Fatechand & Sons, Tumsar.	Do. . .	P. L. .	20	13th January 1938.	Do.
Do. .	(117) Mr. S. Abideen, Nagpur.	Do. . .	P. L. .	81	18th January 1938.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(118) Messrs. Cheniram Jesraj, Nagpur.	Manganese-ore	P. L.	109	19th January 1938.	1 year.
Do.	(119) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	304	24th January 1938.	Do.
Do.	(120) Do.	Do.	P. L.	118	Do.	Do.
Do.	(121) Do.	Do.	P. L.	39	Do.	Do.
Do.	(122) Do.	Do.	P. L.	242	Do.	Do.
Do.	(123) Do.	Do.	P. L.	17	9th February 1938.	Do.
Do.	(124) Mr. K. A. Chiranjivrao, Kamptee	Do.	P. L.	115	12th February 1938.	Do.
Do.	(125) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	188	18th February 1938.	Do.
Do.	(126) Messrs. Pacific Minerals, Ltd., 100, Clive Street, Calcutta.	Do.	P. L.	169	19th February 1938.	Do.
Do.	(127) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	89	24th February 1938.	Do.
Do.	(128) Messrs. Oke Brothers, Nagpur.	Do.	P. L.	83	2nd March 1938.	Do.
Do.	(129) Mr. Shamji Naranji, Ramtek.	Do.	P. L.	238	5th March 1938	Do.
Do.	(130) Messrs. Fatechand & Sons, Tumsar.	Do.	P. L.	90	15th March 1938.	Do.
Do.	(131) Mr. Shriram Seth, Tumsar.	Do.	P. L.	47	17th March 1938.	Do.
Do.	(132) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	14	19th March 1938.	Do.
Do.	(133) Seth Mohanlal Jagannath, Tumsar.	Do.	P. L.	27	22nd March 1938.	Do.
Do.	(134) Mr. S. Lal Mosabani, Mines.	Do.	P. L.	58	23rd March 1938.	Do.
Do.	(135) Seth Mohanlal Jagannath, Tumsar.	Do.	P. L.	46	28th March 1938.	Do.
Do.	(136) Messrs. Fatechand & Sons, Tumsar.	Do.	P. L.	116	9th April 1938	Do.
Do.	(137) Mr. S. Abideen, Nagpur.	Do.	P. L.	88	14th April 1938.	Do.
Do.	(138) Mr. Shriram Seth, Tumsar.	Do.	P. L.	40	Do.	Do.
Do.	(139) The Hon'ble Narayandas Girdhardas, Madras.	Do.	P. L.	32	22nd April 1938.	Do.
Do.	(140) Mr. Shriram Seth, Tumsar.	Do.	P. L.	3	23rd April 1938.	Do.
Do.	(141) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	316	27th April 1938.	Do.
Do.	(142) Do.	Do.	P. L.	93	Do.	Do.
Do.	(143) Do.	Do.	P. L.	178	Do.	Do.
Do.	(144) Messrs. B. Bose & Co., 20 Strand Road, Calcutta.	Do.	P. L.	261	28th April 1938.	Do.
Do.	(145) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	75	7th May 1938	Do.
Do.	(146) K. B. M. M. Mullna, Balaghat.	Do.	P. L.	20	10th May 1938	Do.
Do.	(147) Mr. Madangopal Rungta, Chaibasa.	Do.	P. L.	252	21st May 1938.	Do.
Do.	(148) Seth Balbhadra Sao, Balaghat.	Do.	P. L.	60	10th June 1938.	Do.
Do.	(149) Do.	Do.	P. L.	15	11th June 1938.	Do.

P. L.=*Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(150) Mr. V. V. Kothekar, Balaghat.	Manganese-ore	P. L.	24	28th April 1938.	1 year.
Do.	(151) Messrs. Pacific Minerals, Ltd., 100, Clive Street, Calcutta.	Do.	P. L.	27	13th June 1938.	Do.
Do.	(152) Mr. Shriram Seth, Tumsar.	Do.	P. L.	14	14th June 1938.	Do.
Do.	(153) Do.	Do.	P. L.	19	Do.	Do.
Do.	(154) Messrs. Oke Brothers, Nagpur.	Do.	P. L.	92	16th June 1938.	Do.
Do.	(155) Seth Balbhadra Sao, Balaghat.	Do.	P. L.	22	27th June 1938.	Do.
Do.	(156) Mr. K. A. Chiranjivrao, Kamptee.	Do.	P. L.	231	9th July 1938	Do.
Do.	(157) R. B. Seth Gowardhandas, Tumsar.	Do.	P. L.	89	26th July 1938.	Do.
Do.	(158) Seth Balbhadra Sao, Balaghat.	Do.	P. L.	74	3rd August 1938.	Do.
Do.	(159) Mr. G. L. Jaipuria, Tumsar.	Do.	P. L.	33	9th August 1938.	Do.
Do.	(160) Mr. Shriram Seth, Tumsar.	Do.	P. L.	17	24th August 1938.	Do.
Do.	(161) Seth Balbhadra Sao, Balaghat.	Do.	P. L.	34	26th August 1938.	Do.
Do.	(162) Do.	Do.	P. L.	12	29th August 1938.	Do.
Do.	(163) Do.	Do.	P. L.	7	8th September 1938.	Do.
Do.	(164) Messrs. Chenlram Jesraj, Nagpur.	Do.	P. L.	2	12th September, 1938.	Do.
Do.	(165) Messrs. B. Bose & Co., 20, Strand Road, Calcutta.	Do.	P. L.	118	26th September 1938.	Do.
Do.	(166) Mr. G. L. Jaipuria, Tumsar.	Do.	P. L.	42	8th October 1938.	Do.
Do.	(167) Seth Ghanshyamdas Ramnath, Tumsar.	Do.	P. L.	64	12th October 1938.	Do.
Do.	(168) Seth Balbhadra Sao, Balaghat.	Do.	P. L.	274	4th November 1938.	Do.
Do.	(169) Rai Bahadur Seth Gowardhandas, Tumsar.	Do.	P. L.	8	15th November 1938.	Do.
Do.	(170) Mr. Mohammad Yakub Khan, Balaghat.	Do.	P. L.	58	28th November 1938.	Do.
Do.	(171) Mr. Madan Gopal Rungta, Chaibasa.	Do.	P. L.	68	7th December 1938.	Do.
Do.	(172) Mr. R. P. Mudliar, Balaghat.	Do.	P. L.	26	15th December 1938.	Do.
Do.	(173) Messrs. Bhabutmal & Sons, Balaghat.	Do.	P. L.	44	10th December 1938.	Do.
Do.	(174) Messrs. Fatechand & Sons, Tumsar.	Do.	P. L.	9	22nd December 1938.	Do.
Do.	(175) Do.	Do.	P. L.	24	23rd December 1938.	Do.
Do.	(176) Mr. Kanhaiyalal, Advocate, Balaghat.	Do.	M. L.	70	24th January 1938.	10 years.
Do.	(177) Rao Bahadur Seth Gowardhandas, Tumsar.	Do.	M. L.	6	24th February 1938.	5 years.
Do.	(178) Mr. Diwanchand Jiwar, Balaghat.	Do.	M. L.	61	26th May 1938	15 years.
Do.	(179) Mr. Amritlal P. Trivedi, Balaghat.	Do.	M. L.	77	20th April 1938.	Do.
Do.	(180) Do.	Do.	M. L.	12	Do.	30 years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(181) Rai Bahadur Seth Gowardhandas, Tumsar.	Manganese-ore	M. L.	28	18th July 1938	5 years.
Do.	(182) Mr. Shamji Naranji, Ramtek.	Do.	M. L.	29	6th July 1938	10 years.
Do.	(183) Do.	Do.	M. L.	10	4th July 1938	Do.
Do.	(184) Do.	Do.	M. L.	26	14th May 1938.	15 years.
Do.	(185) Do.	Do.	M. L.	24	13th July 1938.	10 years.
Do.	(186) Do.	Do.	M. L.	166	22nd July 1938.	15 years.
Do.	(187) Messrs. Pacific Minerals, Ltd., 100, Clive Street, Calcutta.	Do.	M. L.	315	26th July 1938.	30 years.
Do.	(188) Mr. Shamji Naranji, Ramtek.	Do.	M. L.	10	12th July 1938.	10 years.
Do.	(189) Do.	Do.	M. L.	13	18th July 1938.	Do.
Do.	(190) Do.	Do.	M. L.	12	22nd May 1938.	Do.
Do.	(191) Messrs. Cheniram Jesraj, Nagpur.	Do.	M. L.	150	16th August 1938.	30 years.
Do.	(192) Mr. Shriram Seth, Tumsar.	Do.	M. L.	21	27th July 1938.	5 years.
Do.	(193) Mr. R. P. Mudliar, Balaghat.	Do.	M. L.	33	30th May 1938.	30 years.
Do.	(194) Mr. Diwanchand Jiwar, Balaghat.	Do.	M. L.	20	23rd July 1938.	10 years.
Do.	(195) Mr. Shriram Seth, Tumsar.	Do.	M. L.	134	25th July 1938.	Do.
Do.	(196) Mr. Ganpatrao Laxmanrao, Nagpur.	Do.	M. L.	2	16th September 1938.	Do.
Do.	(197) Mr. Shamji Naranji, Ramtek.	Do.	M. L.	62	14th October 1938.	Do.
Do.	(198) Messrs. Pacific Minerals, Ltd., 100, Clive Street, Calcutta.	Do.	M. L.	221	18th August 1938.	30 years.
Do.	(199) Mr. G. L. Jaipuria, Tumsar.	Do.	M. L.	67	11th October 1938.	5 years.
Do.	(200) Mr. Namdeo Pandurang Dalal, Bhandara.	Do.	M. L.	20	29th November 1938.	10 years.
Do.	(201) The C. P. Manganese Ore Co., Ltd., Nagpur.	Do.	M. L.	28	2nd December 1938.	30 years.
Do.	(202) Mr. V. V. Kothekar, Balaghat.	Do.	M. L.	15	1st December 1938.	10 years.
Do.	(203) Mr. Shamji Naranji, Ramtek.	Do.	M. L.	62	14th October 1938.	15 years.
Do.	(204) Mr. Shriram Seth, Tumsar.	Do.	M. L.	29	17th November 1938.	5 years.
Betul	(205) C. P. Syndicate, Ltd., Nagpur.	Coal	P. L.	1,028	22nd February 1938.	1 year.
Do.	(206) The Kanhan Valley Coal Co., Ltd., Nagpur.	Do.	P. L.	78	2nd April 1938.	Do.
Do.	(207) Do.	Do.	P. L	368	22nd April 1938.	Do.
Do.	(208) Do.	Do.	P. L.	129	8th March 1938.	Do.
Do.	(209) Do.	Do.	P. L.	119	22nd October 1938.	Do.
Do.	(210) Do.	Do.	P. L.	69	26th February 1938.	Do.
Do.	(211) Mr. K. H. Nag	Do.	P. L.	1,380	8th November 1938.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Betul	(212) Manager, Satpura Minerals, Betul.	Marble	P. L.	90	1st February 1938.	4 months.
Do.	(213) Messrs. Dhanji Deoji & Sons, Betul.	Graphite	P. L.	137	26th May 1938	1 year.
Do.	(214) Tapti Minerals, Betul.	Building & marble stone.	P. L.	77	29th September 1938.	Do.
Do.	(215) Seth B. R. Goenka.	Coal	Supplementary mining lease.	343	1st February 1938.	30 years.
Do.	(216) Messrs. Dhanji Deoji & Sons, Betul.	Red oxide and ochre	Q. L.	107	7th November 1938.	10 years.
Bhandara	(217) Mr. K. A. Chiranjiva Rao.	Manganese-ore	P. L.	112	22nd November 1938.	1 year.
Do.	(218) Rai Bahadur Seth Gowardhandas.	Do.	P. L.	1	3rd January 1938.	Do.
Do.	(219) Do.	Do.	P. L.	7	15th February 1938.	Do.
Do.	(220) Do.	Do.	P. L.	44	15th August 1938.	Do.
Do.	(221) Do.	Do.	P. L.	32	13th January 1938.	Do.
Do.	(222) Mr. G. L. Jaipuria	Do.	P. L.	86	26th May 1938.	Do.
Do.	(223) Mr. S. Abideen	Do.	P. L.	123	28th January 1938.	Do.
Do.	(224) Mr. Ganpat Rao Lakman Rao.	Do.	P. L.	12	9th April 1938	Do.
Do.	(225) Mr. G. L. Jaipuria	Do.	P. L.	42	9th February 1938.	Do.
Do.	(226) Mr. Mohd. Anwar Pasha.	Do.	P. L.	73	19th May 1938.	Do.
Do.	(227) Shree Bajrang Mineral Co.	Do.	P. L.	378	10th March 1938.	Do.
Do.	(228) Mr. Ramkrishna Ramnath.	Do.	P. L.	9	26th May 1938.	Do.
Do.	(229) Do.	Do.	P. L.	41	Do.	Do.
Do.	(230) Do.	Do.	P. L.	182	1st February 1938.	Do.
Do.	(231) Mr. S. Abideen	Do.	P. L.	6	27th January 1938.	Do.
Do.	(232) Mr. K. A. Chiranjiva Rao.	Do.	P. L.	49	3rd January 1938.	Do.
Do.	(233) Mr. S. Abideen	Iron-ore	P. L.	184	20th May 1938.	Do.
Do.	(234) Mr. G. L. Jaipuria	Manganese-ore	P. L.	64	15th February 1938.	Do.
Do.	(235) Mr. K. A. Chiranjiva Rao.	Do.	P. L.	56	22nd June 1938.	Do.
Do.	(236) Do.	Do.	P. L.	129	21st January 1938.	Do.
Do.	(237) Rai Bahadur Seth Gowardhandas.	Do.	P. L.	10	16th February 1938.	Do.
Do.	(238) C. P. Syndicate, Ltd.	Do.	P. L.	55	8th February 1938.	Do.
					29th April 1938.	Do.
Do.	(239) Seth Ghanshyamdas Ramnath.	Do.	P. L.	80	7th March 1938.	Do.
Do.	(240) Mr. F. X. Rebello	Do.	P. L.	147	8th March 1938.	Do.
Do.	(241) The C. P. Syndicate, Ltd.	Do.	P. L.	7	8th February 1938.	Do.
Do.	(242) Seth Shriram	Do.	P. L.	12	20th May 1938	Do.
Do.	(243) Seth Ghanshyamdass.	Do.	P. L.	16	15th August 1938.	Do.
Do.	(244) Mr. F. X. Rebello	Do.	P. L.	16	8th March 1938.	Do.

P. L.—*Prospecting License.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara	(245) Rai Bahadur Kuwarlalsingh.	Manganese-ore	P. L.	126	2nd March 1938.	1 year.
Do.	(246) Mr. F. X. Rebello	Do.	P. L.	3	3rd November 1938.	Do.
Do.	(247) Do.	Do.	P. L.	40	28th July 1938.	Do.
Do.	(248) Messrs. Nathulal Domaji Vaidya.	Do.	P. L.	31	22nd July 1938.	Do.
Do.	(249) Mr. Daya Bhimji	Do.	P. L.	120	20th July 1938.	Do.
Do.	(250) Mr. S. Abideen	Do.	P. L.	57	23rd April 1938.	Do.
Do.	(251) Mr. F. X. Rebello	Do.	P. L.	8	13th June 1938	Do.
Do.	(252) Do.	Do.	P. L.	37	8th October 1938.	Do.
Do.	(253) Do.	Do.	P. L.	8	22nd July 1938.	Do.
Do.	(254) Messrs. Vrajlal Manilal & Co., Gondia.	Do.	P. L.	683	1st December 1938.	Do.
Do.	(255) Mr. Abideen	Pottery clay	P. L.	109	12th May 1938.	Do.
Do.	(256) Do.	Do.	P. L.	85	22nd June 1938.	Do.
Do.	(257) Rai Bahadur Seth Gowardhandas.	Manganese-ore	M. L.	8	21st March 1938.	15 years.
Do.	(258) Mr. G. Sanyal, Manager, Nagpur, Bhandara Manganese Ore Co., Ltd.	Do.	M. L.	150	4th October 1938.	30 years.
Do.	(259) Rai Bahadur Seth Gowardhandas.	Do.	M. L.	6	29th April 1938.	5 years.
Do.	(260) Mr. K. A. Chiranjiva Rao.	Do.	M. L.	10	20th August 1938.	10 years.
Do.	(261) Messrs. Oko Brothers.	Do.	M. L.	38	15th December 1938.	30 years.
Do.	(262) Messrs. B. P. Byramji & Co.	Do.	M. L.	8	16th August 1938.	5 years.
Bilaspur	(263) Mr. Mulji Jagmal	Limestone	M. L.	36	22nd August 1938.	Do.
Do.	(264) Do.	Do.	M. L.	24	1st August 1938.	Do.
Do.	(265) Mr. Jairam Valji	Do.	M. L.	203	25th April 1938.	10 years.
Do.	(266) Mr. Sudharam	Do.	Q. L.	2		
Do.	(267) Messrs. S. Barati & H. K. Zakaria Bara Lime Stone Co.	Do.	Q. L.	3	14th February 1938.	3 years.
Do.	(268) Babu Arjun Purohit.	Do.	Q. L.	5	26th August 1938.	10 years.
Do.	(269) Chhota Nagpur Forest Syndicate, Calcutta.	Do.	Q. L.	2	10th December 1938.	Do.
Chanda	(270) The Chanda Mining and Industrial Company, Chanda.	Mica	P. L.	595	6th February 1938.	1 year.
Do.	(271) Mrs. Mohamad Hussain, R. Hashambhoy, General Merchant, Civil Lines, Chanda.	Yellow ochre	P. L.	65	7th June 1938	Do.
Do.	(272) Do.	Do.	Q. L.	11	17th June 1938.	10 years.
Do.	(273) Mrs. Henry, Mr. Hance, M.Sc., Mining Engineer, Calcutta.	Iron-ore	Q. L.	225	20th September 1938.	1 year.
Do.	(274) Do.	Limestone	Q. L.	122	Do	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chanda .	(275) Mr. Henry, Mr. Hance, M.Sc., Mining Engineer, Calcutta.	Coal . . .	P. L. .	987	20th September 1938.	1 year.
Do. .	(276) Hon'ble Sir M. B. Dadabhoy, K. C. S. I., Kt., Bar-at-Law, Nagpur.	Sand . . .	Q. L. .	105	29th June 1938.	10 years.
Do. .	(277) Hon'ble Mrs. Narayandas Girdhardas, Madras.	Coal . . .	P. L. .	552	8th October 1938.	1 year.
Chhindwara .	(278) Seth Bansidhar Ramniwas Goenka.	Do. . . .	M. L. .	102	5th September 1938.	30 years.
Do. .	(279) Mr. M. D'Costa .	Manganese ore .	M. L. .	82	4th February 1938.	5 years.
Do. .	(280) Messrs. S. C. Cambata & Co., Ltd.	Coal . . .	M. L. .	1,108	30th August 1938.	30 years.
Do. .	(281) Mr. P. S. Sial .	Do. . . .	M. L. .	420	7th September 1938.	Do.
Do. .	(282) Rai Sahib Seth Phulchand.	Manganese ore .	M. L. .	35	24th June 1938.	10 years.
Do. .	(283) The Hirdagarh Collieries, Ltd.	Coal . . .	Supplementary M. L.	30	16th September 1938.	Period ending 25th October 1950.
Do. .	(284) The Amalgamated Coal Fields, Ltd.	Do. . . .	M. L. .	2,839	1st April 1938	30 years.
Do. .	(285) Mr. M. D'Costa .	Manganese-ore .	P. L. .	14	23rd May 1938.	1 year.
Do. .	(286) Messrs. N. H. Ojha & Co., Ltd.	Coal . . .	P. L. .	245	8th March 1938.	Do.
Do. .	(287) Seth Jagannath Sheonarain.	Manganese ore .	P. L. .	340	6th June 1938	Do.
Do. .	(288) Mr. M. D'Costa .	Do. . .	P. L. .	41	22nd January 1938.	Do.
Do. .	(289) Seth Bansidhar Ramniwas Goenka.	Do. . .	P. L. .	15	2nd February 1938.	Do.
Do. .	(290) The Hon'ble Mr. Narayandas Girdhardas.	Do. . .	P. L. .	163	5th March 1938.	Do.
Do. .	(291) Seth Mohanlal Jagannath.	Do. . .	P. L. .	17	15th February 1938.	Do.
Do. .	(292) Rai Sahib Seth Phulchand.	Do. . .	P. L. .	34	3rd January 1938.	Do.
Do. .	(293) Mr. M. D'Costa .	Do. . .	P. L. .	52	10th February 1938.	Do.
Do. .	(294) Rai Bahadur Seth Gowardhan Das.	Do. . .	P. L. .	18	18th March 1938.	Do.
Do. .	(295) Do. .	Do. . .	P. L. .	36	6th April 1938	Do.
Do. .	(296) Do. .	Do. . .	P. L. .	22	Do. .	Do.
Do. .	(297) Do. .	Do. . .	P. L. .	11	Do. .	Do.
Do. .	(298) Mr. S. Abideen .	Do. . .	P. L. .	214	14th February 1938.	Do.
Do. .	(299) Rai Sahib Seth Phulchand.	Do. . .	P. L. .	120	10th March 1938.	Do.
Do. .	(300) Messrs. Mangalsingh Ishwarsingh Hanspal.	Coal . . .	P. L. .	309	1st June 1938	Do.
Do. .	(301) Rai Bahadur Seth Goverdhan Das.	Manganese ore .	P. L. .	33	18th March 1938.	Do.
Do. .	(302) Mr. S. Abideen .	Do. . .	P. L. .	148	6th April 1938.	Do.
Do. .	(303) Mr. K. A. Chiranjiva Rao.	Do. . .	P. L. .	31	16th February 1938.	Do.
Do. .	(304) Do. .	Do. . .	P. L. .	114	Do. .	Do.
Do. .	(305) The Hon'ble Mr. Narayandas Girdhardas.	Do. . .	P. L. .	72	5th March 1938.	Do.
Do. .	(306) Mr. K. A. Chiranjiva Rao.	Do. . .	P. L. .	33	4th May 1938	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara	(307) Seth Ahsan Hussain Abdul Ali.	Coal	P. L.	376	26th March 1938.	1 year.
Do.	(308) Do.	Do.	P. L.	27	16th May 1938.	Do.
Do.	(309) Mr. Shree Ram Seth.	Do.	P. L.	34	14th October 1938.	Do.
Do.	(310) Mr. S. Abideen	Manganese-ore	P. L.	121	22nd August 1938.	Do.
Do.	(311) Messrs. Cheniram Jesraj.	Do.	P. L.	53	10th June 1938.	Do.
Do.	(312) Do.	Do.	P. L.	27	Do.	Do.
Do.	(313) Mr. K. A. Chiranjiva Rao.	Do.	P. L.	173	24th September 1938.	Do.
Do.	(314) Shreemant K. S. Chitnavis.	Do.	P. L.	28	15th December 1938.	Do.
Do.	(315) Seth Ramkrishna Ramnath Agarwal.	Do.	P. L.	32	18th October 1938.	Do.
Do.	(316) Do.	Do.	P. L.	14	29th April 1938.	Do.
Do.	(317) Mr. S. Abideen	Do.	P. L.	128	22nd August 1938.	Do.
Do.	(318) Shreemant K. S. Chitnavis.	Do.	P. L.	845	15th December 1938.	Do.
Do.	(319) Mr. Chapsi Bhai V Jasani.	Do.	P. L.	130	8th March 1938.	Do.
Do.	(320) Do.	Do.	P. L.	153	29th March 1938.	Do.
Do.	(321) Messrs. Oke Brothers.	Do.	P. L.	158	17th December 1938.	Do.
Do.	(322) Mr. S. Abideen	Do.	P. L.	50	22nd August 1938.	Do.
Do.	(323) Mr. K. A. Chiranjiva Rao.	Do.	P. L.	38	13th August 1938.	Do.
Do.	(324) Rai Bahadur Seth Gowardhandas.	Do.	P. L.	3	6th April 1938	Do.
Do.	(325) Seth Ramkrishna Ramnath Agarwal.	Do.	P L.	80	18th October 1938.	Do.
Do.	(326) Do.	Do.	P. L.	33	Do.	Do.
Do.	(327) Mr. Chapsi Bhai V. Jasani.	Do.	P. L.	170	1st September 1938.	Do.
Do.	(328) Messrs. Newton Chickli Collieries, Ltd.	Coal	P. L.	78	10th May 1938.	Do.
Do.	(329) Seth Ramkrishna Ramnath Agarwal.	Manganese-ore	P. L.	15	18th October 1938.	Do.
Do.	(330) Mr. S. C. Combata, J. P.	Coal	P. L.	401	1st November 1938.	Do.
Do.	(331) Seth Ramkrishna Ramnath Agarwal.	Manganese ore	P. L.	20	18th October 1938.	Do.
Do.	(332) Mr. M. D'Costa	Do.	P. L.	58	22nd December 1938.	Do.
Do.	(333) Mr. Chapsi Bhai V. Jasani.	Do.	P. L.	33	5th October 1938.	Do.
Do.	(334) R. S. Seth Kochorimal Sukhlal.	Do.	P. L.	76	5th September 1938.	Do.
Do.	(335) Mr. P. S. Sial	Coal	P. L.	242	22nd November 1938.	Do.
Do.	(336) Mr. Shamji Naranji.	Manganese-ore	P. L.	227	17th November 1938.	Do.
Drug	(337) Mr. P. C. Lal	Flooring stone	Q. L.	15	2nd July 1937	10 years.
Do.	(338) Rai Bahadur Seth Govardhandas.	Lead and silver	P. L.	25	2nd February 1938.	1 year.
Hoshangabad	(339) Mr. Ballram Pandurang Mokadam, Mining Engineer of Jubbulpore.	Clay	P. L.	34	5th July 1938	Do.
Jubbulpore	(340) Mr. J. C. Mance	Zeolites	P. L.	832	13th March 1938.	Do.

P. L.—*Prospecting License.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbulpore .	(341) The Jubbulpore Chemical Company Ltd., Jubbulpore.	Coal . .	P. L. .	225	6th September 1938.	1 year.
Do. .	(342) Mr. Manmohandass.	Red ochre and oxide of iron.	Q. L. .	43	17th October 1938.	10 years.
Do. .	(343) Mr. Shiolal .	Barytes .	P. L. .	12	2nd November 1938.	1 year.
Do. .	(344) Do. . .	Do. . . .	P. L. .	97	Do. .	Do.
Do. .	(345) Do. . .	Do. . . .	P. L. .	28	10th November 1938.	Do.
Do. .	(346) Do. . .	Do. . . .	P. L. .	169	7th November 1938.	Do.
Do. .	(347) Mr. Kedar Prashad.	Bauxite . . .	P. L. .	748	25th November 1938.	Do.
Do. .	(348) Do. .	Do. . .	P. L. .	63	15th November 1938.	Do.
Do. .	(349) Messrs. Dyre's Stone Lime Co., Ltd.	Do. . .	P. L. .	157	14th November 1938.	Do.
Do. .	(350) Mr. Raiyaram Melaram.	Limestone . .	Q. L. .	25	10th February 1938.	10 years.
Do. .	(351) Mr. G. H. Cook .	Yellow Fullers earth	Q. L. .	1	6th May 1938	Do.
Do. .	(352) Do. .	Stone . . .	Q. L. .	1	21st February 1938.	Do.
Do. .	(353) Mr. N. M. Dubash	Limestone . .	Q. L. .	10	25th August 1938.	Do.
Do. .	(354) Mr. S. P. Gour .	Bauxite . . .	P. L. .	54	7th December 1938.	1 year.
Do. .	(355) Seth Gangadhar Rameshwar Dass.	Bartyes . .	P. L. .	124	17th December 1938.	Do.
Do. .	(356) Mr. S. P. Gour .	Manganese-ore .	P. L. .	45	12th December 1938.	Do.
Do. .	(357) Messrs. Dyer's Stone Lime Co., Ltd.	Do. . .	P. L. .	38	30th May 1938.	Do.
Do. .	(358) Mr. S. P. Gour .	Bauxite . . .	P. L. .	262	6th September 1938.	Do.
Do. .	(359) Messrs. Venkat Raman & Sons.	Do. . . .	P. L. .	16	8th November 1938.	Do.
Do. .	(360) Do. .	Do. . . .	P. L. .	11	Do. .	Do.
Do. .	(361) Mr. Jailal .	Clay . . .	Q. L. .	2	29th October 1938.	Do.
Do. .	(362) Mr. Dhanpatsingh	Do. . . .	Q. L. .	1	14th November 1938.	Do.
Do. .	(363) Mr. Mukandilal .	Do. . . .	Q. L. .	2	Do. .	Do.
Do. .	(364) Mr. Abdul Hafiz .	Do. . . .	Q. L. .	1	17th December 1938.	Do.
Do. .	(365) Mr. Rameshwar Rao Gaikwad.	Do. . . .	Q. L. .	1	2nd December 1938.	Do.
Do. .	(366) Mr. Bhagwan .	Do. . . .	Q. L. .	1	4th November 1938.	Do.
Do. .	(367) Jwala Prashad .	Do. . . .	P. L. .	18	Do. .	Do.
Do. .	(368) Ballilal . .	Do. . . .	P. L. .	39	Do. .	Do.
Do. .	(369) Do. . .	Do. . . .	P. L. .	19	10th September 1938.	Do.
Do. .	(370) J. R. Hargreaves	Do. . . .	P. L. .	82	5th December 1938.	Do.
Do. .	(371) T. C. Bayam & Co.	Do. . . .	P. L. .	18	12th December 1938.	Do.
Do. .	(372) Mr. Govind Prashad.	Soapstone . .	P. L. .	100	2nd October 1938.	Do.
Do. .	(373) Kedar Prashad .	Red ochre . .	P. L. .	99	6th September 1938.	Do.
Do. .	(374) J. P. Dutt .	Red earth . .	P. L. .	27	29th October 1938.	Do.
Do. .	(375) Rajaram Gowardhandass.	Soapstone . .	P. L. .	7	22nd October 1938.	Do.
Do. .	(376) S. Lall . .	Do. . . .	P. L. .	19	27th November 1938.	Do.

P. L.—*Prospecting License.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbulpore .	(377) Ramlall . .	Soapstone . .	P. L. .	110	26th October 1938.	1 year.
Do. .	(378) Messrs. Dyer's Stone Lime Co., Ltd.	Hæmatite . .	P. L. .	19	22nd August 1938.	Do.
Nagpur .	(379) Messrs. Dhanji Deoji & Sons, Nagpur.	Manganese ore .	P. L. .	12	12th January 1938.	Do.
Do. .	(380) Seth Jagannath Sheonarain, Kamptee.	Do. . .	P. L. .	9	17th January 1938.	Do.
Do. .	(381) Mr. K. S. Chitnavis, Nagpur.	Do. . .	P. L. .	1,143	27th January 1938.	Do.
Do. .	(382) Seth Mohanlal Jagannath, Tumsar.	Do. . .	P. L. .	194	29th January 1938.	Do.
Do. .	(383) Rai Saheb Seth Fulchand, Kamptee.	Do. . .	P. L. .	152	Do. .	Do.
Do. .	(384) Rai Bahadur Seth Gowardhandas, Tumsar.	Do. . .	P. L. .	81	22nd January 1938.	Do.
Do. .	(385) Do. .	Do. . .	P. L. .	11	5th February 1938.	Do.
Do. .	(386) Mr. K. A. Chiranjiva Rao, Kamptee.	Do. . .	P. L. .	47	Do. .	Do.
Do. .	(387) Mr. G. L. Jaipuria, Tumsar.	Do. . .	P. L. .	11	Do. .	Do.
Do. .	(388) Do. .	Do. . .	P. L. .	50	Do.	Do.
Do. .	(389) Mr. S. Abideen, Nagpur.	Do. . .	P. L. .	13	Do.	Do.
Do. .	(390) Do. .	Do. . .	P. L. .	148	Do. .	Do
Do. .	(391) Rai Bahadur Seth Gowardhandas, Tumsar.	Do. . .	P. L. .	61	9th February 1938.	Do.
Do. .	(392) Do. .	Do. . .	P. L. .	30	Do.	Do.
Do. .	(393) Mr. W. J. Packwood, Nagpur.	Do. . .	P. L. .	388	Do.	Do.
Do. .	(394) Seth Shreeram, Tumsar.	Do. . .	P. L. .	422	Do. .	Do.
Do. .	(395) Seth Ramkrishna Ramnath, Kamptee.	Do. . .	P. L. .	3	Do.	Do.
Do. .	(396) Mr. Bhawanji Naranji, Ramtek.	Do. . .	P. L. .	26	Do. .	Do.
Do. .	(397) Do. .	Do. . .	P. L. .	36	Do. .	Do.
Do. .	(398) Do. .	Do. . .	P. L. .	23	15th February 1938.	Do.
Do. .	(399) Do. .	Do. . .	P. L. .	28	Do. .	Do.
Do. .	(400) Haji Khawaja Mian, Kamptee.	Do. . .	P. L. .	58	Do. .	Do.
Do. .	(401) Do. .	Do. . .	P. L. .	42	Do. .	Do.
Do. .	(402) Mr. M. D'Costa, Nagpur.	Do. . .	P. L. .	53	Do. .	Do.
Do. .	(403) Do. .	Do. . .	P. L. .	64	Do. .	Do.
Do. .	(404) Do. .	Do. . .	P. L. .	87	Do. .	Do.
Do. .	(405) Seth Mohanlal Jagannath, Tumsar.	Do. . .	P. L. .	33	Do. .	Do.
Do. .	(406) Do. .	Do. . .	P. L. .	89	25th February 1938.	Do.
Do. .	(407) Mr. K. A. Chiranjiva Rao, Kamptee.	Do. . .	P. L. .	91	Do. .	Do.
Do. .	(408) Messrs. Dhanji Deoji & Sons, Nagpur.	Do. . .	P. L. .	25	5th March 1938.	Do.
Do. .	(409) Mr. W. J. Packwood, Nagpur.	Do. . .	P. L. .	303	Do. .	Do.
Do. .	(410) Mr. G. L. Jaipuria, Tumsar.	Do. . .	P. L. .	4	Do. .	Do.
Do. .	(411) Seth Ramkrishna Ramnath, Kamptee.	Do. . .	P. L. .	44	10th March 1938.	Do.
Do. .	(412) Mr. G. L. Jaipuria, Tumsar.	Do. . .	P. L. .	13	11th March 1938.	Do.

P. L.—*Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(413) Messrs. Dhanji Deoji & Sons, Nagpur.	Manganese-ore	P. L.	46	22nd March 1938.	1 year.
Do.	(414) Seth Ramkrishna Ramnath, Kamptee.	Do.	P. L.	20	Do.	Do.
Do.	(415) Messrs. Cheniram Jesraj, Nagpur.	Do.	P. L.	29	18th March 1938.	Do.
Do.	(416) Mr. Shamji Naranji, Ramtek.	Do.	P. L.	6	22nd March 1938.	Do.
Do.	(417) Messrs. Dhanji Deoji & Sons, Nagpur.	Do.	P. L.	42	18th March 1938.	Do.
Do.	(418) Mr. Bhawanji Naranji, Ramtek.	Do.	P. L.	44	12th April 1938.	Do.
Do.	(419) Mr. K. S. Chitnavis, Nagpur.	Do.	P. L.	90	Do.	Do.
Do.	(420) Mr. M. D'Costa, Nagpur.	Do.	P. L.	75	29th April 1938.	Do.
Do.	(421) Do.	Do.	P. L.	64	Do.	Do.
Do.	(422) Mr. S. Abideen	Do.	P. L.	52	Do.	Do.
Do.	(423) Rai Sahib Seth Fulchand, Kamptee, Nagpur.	Do.	P. L.	39	22nd April 1938.	Do.
Do.	(424) Mr. Bhawanji Naranji, Ramtek.	Do.	P. L.	11	13th April 1938.	Do.
Do.	(425) Rai Bahadur Seth Goverdhandas, Tumsar.	Do.	P. L.	47	12th April 1938.	Do.
Do.	(426) Mr. Bhawanji Naranji, Ramtek.	Do.	P. L.	135	29th March 1938.	Do.
Do.	(427) Do.	Do.	P. L.	57	18th April 1938.	Do.
Do.	(428) Haji Khawaja Mian, Kamptee.	Do.	P. L.	42	29th April 1938.	Do.
Do.	(429) Seth Ratanlal Karnidan Dhadiwal, Nagpur.	Do.	P. L.	654	Do.	Do.
Do.	(430) Messrs. A. H. Wasudeo Rao & Bros., Nagpur.	Do.	P. L.	79	Do	Do.
Do.	(431) Mr. N. D. Zal, Kamptee.	Do.	P. L.	1	26th April 1938.	Do.
Do.	(432) Mr. Mangal Singh, Nagpur.	Limestone	P. L.	14	8th May 1938	Do.
Do.	(433) Haji Khawaja Mian, Kamptee.	Manganese-ore	P. L.	53	17th May 1938	Do.
Do.	(434) Seth Mohanlal Jagannath, Tumsar.	Do.	P. L.	7	18th May 1938	Do.
Do.	(435) Haji Khwaja Mian, Kamptee.	Do.	P. L.	111	24th May 1938	Do.
Do.	(436) Messrs. Dhanji Deoji & Sons, Nagpur.	Do.	P. L.	235	28th May 1938	Do.
Do.	(437) Do.	Do.	P. L.	108	Do.	Do.
Do.	(438) Mr. L. D. Lele, Nagpur.	Limestone	P. L.	35	2nd June 1938	Do.
Do.	(439) Mr. Shree Ram, Tumsar.	Manganese-ore	P. L.	11	Do.	Do.
Do.	(440) Mr. K. A. Chiranjiva Rao, Kamptee.	Do.	P. L.	15	14th June 1938.	Do.
Do.	(441) The C. P. Syndicate, Ltd., Nagpur.	Do.	P. L.	53	5th October 1937.	Do.
Do	(442) Mr. Shamji Naranji, Ramtek.	Do.	P. L.	93	28th June 1938.	Do.
Do.	(443) Mr. Shree Ram, Tumsar.	Do.	P. L.	19	22nd June 1938.	Do.
Do.	(444) Mr. Ganpatrao Laxman Rao, Nagpur.	Do.	P. L.	41	Do.	Do.
Do.	(445) Do.	Do.	P. L.	25	Do.	Do.

P. L.=*Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(446) Seth Ghanshiamdas Ramnath, Tumsar.	Manganese-ore .	P. L. .	32	11th May 1938	One year.
Do. .	(447) Rai Sahib Seth Phulchand, Kamptee.	Do. . .	P. L. .	2	2nd June 1938	Do.
Do. .	(448) Haji Khwaja Mian, Kamptee.	Do. . .	P. L. .	104	4th July 1938	Do.
Do. .	(449) Mr. G. L. Jaipuria, Tumsar.	Do. . .	P. L. .	33	22nd June 1938.	Do.
Do. .	(450) Mr. V. K. Mudliar, Nagpur.	Building stone .	P. L. .	21	15th July 1938	Do.
Do. .	(451) Mr. K. A. Chiranjiva Rao, Kamptee.	Manganese-ore .	P. L. .	19	Do. .	Do.
Do. .	(452) Mr. K. S. Chitnavis, Nagpur.	Wolfram . .	P. L. .	634	4th July 1938	Do.
Do. .	(453) Mr. S. Abideen, Nagpur.	Manganese-ore .	P. L. .	47	24th May 1938	Do.
Do. .	(454) Mr. Ganpatrao Laxmanrao, Nagpur.	Do. . .	P. L. .	117	24th July 1938	Do.
Do. .	(455) Rai Bahadur Seth Gowardandas, Nagpur.	Do. . .	P. L. .	7	28th July 1938	Do.
Do. .	(456) Mr. Shamji Naranji, Ramtek.	Do. . .	P. L. .	52	Do. .	Do.
Do. .	(457) Do. .	Do. . .	P. L. .	11	Do. .	Do.
Do. .	(458) Do. .	Do. . .	P. L. .	10	Do. .	Do.
Do. .	(459) Mr. K. A. Chiranjiva Rao, Kamptee.	Do. . .	P. L. .	22	2nd August 1938.	Do.
Do. .	(460) R. S. Seth Fulchand, Kamptee.	Do. . .	P. L. .	20	Do. .	Do.
Do. .	(461) Messrs. Champsi Bhai, Gondia.	Do. . .	P. L. .	105	24th July 1938	Do.
Do. .	(462) Mr. Ganpatrao Laxmanrao, Nagpur	Do. . .	P. L. .	344	20th August 1938.	Do.
Do. .	(463) Do. .	Do. . .	P. L. .	140	15th August 1938.	Do.
Do. .	(464) Mr. G. L. Jaipuria, Tumsar.	Do. .	P. L. .	25	Do. .	Do.
Do. .	(465) Mr. Shamji Naranji, Ramtek.	Do. . .	P. L. .	39	Do. .	Do.
Do. .	(466) Mr. Mohanlal Jagannath, Tumsar.	Do. . .	P. L. .	35	24th August 1938.	Do.
Do. .	(467) Mr. N. D. Zal, Kamptee.	Do. . .	P. L. .	18	2nd August 1938.	Do.
Do. .	(468) The Nagpur Industrial Co., Nagpur.	Red and yellow oxide	P. L. .	15	10th September 1938.	Do.
Do. .	(469) Mr. F. X. Rebello, Nagpur.	Limestone . .	P. L. .	9	Do. .	Do.
Do. .	(470) R. B. Seth Gowardhandas, Tumsar.	Manganese-ore .	P. L. .	18	2nd September 1938.	Do.
Do. .	(471) Do. .	Do. . .	P. L. .	43	22nd June 1938.	Do.
Do. .	(472) Shreeram Seth, Tumsar.	Do. . .	P. L. .	16	18th August 1938.	Do.
Do. .	(473) The Hon'ble Mr. Naraindas Girdhardas, Madras.	Do. . .	P. L. .	56	19th May 1938	Do.
Do. .	(474) Seth Ramkrishna Ramnath, Kamptee.	Do. . .	P. L. .	9	22nd September 1938.	Do.
Do. .	(475) Mr. Madan Gopal Rungta, Chaibasa.	Do. . .	P. L. .	7	29th August 1938.	Do.
Do. .	(476) Seth Shreeram, Tumsar.	Do. . .	P. L. .	21	22nd September 1938.	Do.
Do. .	(477) Mr. Ramkrishna Ramnath, Kamptee.	Do. . .	P. L. .	9	10th September 1938.	Do.
Do. .	(478) Messrs. Cheniram Jesraj, Nagpur.	Do. . .	P. L. .	18	Do. .	Do.

P. L. = *Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(479) Mr. F. X. Rebello, Nagpur.	Manganese-ore	P. L.	35	22nd September 1938.	One year.
Do.	(480) Mr. Bhawanji Naranji, Ramtek.	Do.	P. L.	7	Do.	Do.
Do.	(481) Do.	Do.	P. L.	400	Do.	Do.
Do.	(482) Mr. Ganpatrao Laxamanrao, Nagpur.	Do.	P. L.	5	Do.	Do.
Do.	(483) Mr. Shamji Naranji, Ramtek.	Do.	P. L.	61	10th September 1938.	Do.
Do.	(484) Mr. Bhavanji Naranji, Ramtek.	Do.	P. L.	63	5th October 1938.	Do.
Do.	(485) Haji K. Mian, Kamptee.	Do.	P. L.	270	18th October 1938.	Do.
Do.	(486) Messrs. Champsi Bhai & V. J. Bhatia, Gondia.	Do.	P. L.	79	28th October 1938.	Do.
Do.	(487) Mr. Bhawanji Naranji, Ramtek.	Do.	P. L.	10	Do.	Do.
Do.	(488) Seth Ghanshiamdas Ramnath, Tumsar.	Do.	P. L.	68	Do.	Do.
Do.	(489) Rai Sahib Seth Fulchand, Kamptee.	Do.	P. L.	80	14th November 1938.	Do.
Do.	(490) Messrs. Champsi Bhai & V. J. Bhatia, Gondia.	Do.	P. L.	92	22nd November 1938.	Do.
Do.	(491) Rai Bahadur Seth Gowardhandas, Tumsar.	Do.	P. L.	31	Do.	Do.
Do.	(492) Do.	Do.	P. L.	55	Do.	Do.
Do.	(493) Seth Ramkrishna Ramnath, Kamptee.	Do.	P. L.	75	Do.	Do.
Do.	(494) Do.	Do.	P. L.	27	5th November 1938.	Do.
Do.	(495) Do.	Do.	P. L.	5	18th October 1938.	Do.
Do.	(496) Seth Shreeram, Tumsar.	Do.	P. L.	25	14th November 1938.	Do.
Do.	(497) Messrs. A. H. Wasudeorao & Bros., Nagpur.	Do.	P. L.	130	5th November 1938.	Do.
Do.	(498) Messrs. Dedraj Dhandhania, Nagpur.	Do.	P. L.	163	4th January 1938.	Do.
Do.	(499) Mr. Bhavanji Naranji, Ramtek.	Do.	P. L.	48	12th January 1938.	Do.
Do.	(500) Rai Sahib Seth Fulchand, Kamptee.	Do.	M. L.	1	1st February 1938.	20 years.
Do.	(501) Messrs. Kartarsingh Jaswantsingh, Nagpur.	Limestone	Q. L.	6	2nd March 1938.	10 years.
Do.	(502) Mr. Ganpatrao Laxmanrao, Nagpur.	Manganese ore	M. L.	21	22nd February 1938.	Do.
Do.	(503) Mr. Shamji Naranji, Ramtek.	Do.	M. L.	14	1st March 1938	Do.
Do.	(504) Do.	Do.	M. L.	47	Do.	Do.
Do.	(505) Mr. Shreeram, Tumsar.	Do.	M. L.	66	15th February 1938.	5 years.
Do.	(506) Mr. K. R. Oke, Nagpur.	Building stone	Q. L.	9	23rd May 1938	10 years.
Do.	(507) Mr. R. P. Mudliar, Balaghat.	Manganese-ore	M. L.	206	5th May 1938	30 years.
Do.	(508) Mr. Shamji, Naranji, Ramtek.	Do.	M. L.	51	19th April 1938	10 years.
Do.	(509) Do.	Do.	M. L.	13	14th May 1938	Do.
Do.	(510) Mr. V. S. Phadke, Nagpur.	Clay	Q. L.	4	18th May 1938	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(511) Messrs. Dhanji Deoji & Sons, Betul.	Manganese-ore	M. L.	68	11th June 1938.	30 years.
Do.	(512) Mr. N. D. Zal, Kamptee.	Do.	M. L.	11	21st June 1938	Do.
Do.	(513) Mr. K. G. Khandekar, Nagpur.	Sand	Q. L.	22	16th May 1938	One year.
Do.	(514) C. P. Syndicate, Ltd., Nagpur.	Manganese-ore	M. L.	73	4th July 1938	5 years.
Do.	(515) Mr. M. D'Costa, Nagpur.	Do.	M. L.	23	14th October 1938.	20 years.
Do.	(516) Messrs. Oke Bros., Nagpur.	Boulders and Murrum.	Q. L.	24	22nd August 1938.	10 years.
Do.	(517) Mr. Shamji Naranji, Ramtek.	Manganese-ore	M. L.	1	14th October 1938.	Do.
Do.	(518) Seth Jagannath Sheonarayan, Kamptee.	Do.	M. L.	9	8th October 1938.	5 years.
Do.	(519) Mr. Meghraj Asram Patil, Nagpur.	Building stone	Q. L.	6	14th October 1938.	10 years.
Do.	(520) Mr. Ramkrishna Ramnath, Kamptee.	Do.	Q. L.	38	12th November 1938.	7 years.
Do.	(521) Mr. K. R. Oke, Nagpur.	Do.	Q. L.	3	17th November 1938.	10 years.
Do.	(522) Messrs. Cheniram Jesraj, Nagpur.	Manganese-ore	M. L.	28	16th August 1938.	30 years.
Do.	(523) Seth Mohanlal Jaggannath, Tumsar.	Do.	M. L.	63	19th November 1938.	20 years.
Do.	(524) Mr. R. J. Poddar, Nagpur.	Do.	M. L.	16	21st November 1938.	30 years.
Do.	(525) C. P. Manganese Ore, Co., Ltd., Nagpur.	Do.	M. L.	6	2nd December 1938.	Do.
Do.	(526) The Hon'ble Mr. Naraindas Girdhardas, Madras.	Do.	M. L.	94	10th December 1938.	Do.
Raipur	(527) Mr. Damji Sheoji, Railway Contractor.	Flooring stone	Q. L.	3	12th January 1938.	5 years.
Do.	(528) Messrs. Pancha Bhai & Sons and Raghoo, Contractor.	Clay	Q. L.	7	28th April 1938	10 years.
Do.	(529) Mr. Mithoomal, Railway Contractor.	Limestone	Q. L.	2	15th June 1938.	Do.
Do.	(530) Mr. Nanakchand, Railway Contractor.	Building stone	Q. L.	12	24th September 1938.	Do.
Do.	(531) Do.	Limestone and building stone.	P. L.	64	13th October 1938.	One year.
Do.	(532) Do.	Building stone	P. L.	12	30th March 1938.	Do.
Do.	(533) Mithoomal, Railway Contractor.	Limestone and building stone.	P. L.	4	8th October 1938.	Do.
Yeotmal	(534) Rai Bahadur Bansilal Abirchand Mining Syndicate, Kamptee.	Coal	M. L.	1,590	15th November 1938.	30 years.
Do.	(535) Mr. F. X. Rebello of Nagpur.	Limestone	P. L.	26	6th November 1937.	One year.
Do.	(536) Mr. Ganpatrao Laxmanrao of Nagpur.	Coal	P. L.	151	8th October 1937.	Do.
Do.	(537) Mr. A. H. Wasudeorao of Nagpur.	Limestone	P. L.	18	8th December 1937.	Do.
Do.	(538) Mr. T. Rajlu Naidu of Nagpur.	Do.	Q. L.	1	12th July 1938	10 years.
Do.	(539) Do.	Do.	Q. L.	2	29th July 1938.	Do.
Do.	(540) Mr. M. D'Costa of Nagpur.	Do.	Q. L.	12	30th August 1938.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.* Q. L.=*Quarry Lease.*

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur	(541) The Hon'ble Mr. Narayandas Girdhardas.	Gold	P. L.	1293·70	30th March 1938.	One year.
Do.	(542) Sri Vishnu Nimbkar.	Barytes	P. L.	32·66	9th April 1938	Do.
Do.	(543) The Hon'ble Mr. Narayandas Girdhardas.	Gold	P. L.	6268·70	30th March 1938.	Do.
Do.	(544) Sri Y. Dasaradarami.	Barytes	P. L.	12·21	23rd June 1938.	Do.
Do.	(545) Sri B. P. Sesha Reddi.	Do.	P. L.	85·57	22nd July 1938	Do.
Do.	(546) Sri Vishnu Nimbkar.	Do.	P. L.	257	6th August 1938.	Do.
Do.	(547) Do.	Do.	P. L.	49·95	11th August 1938.	Do.
Do.	(548) S. S. Guzdar	Do.	M. L.	20	1st February 1938.	30 years.
Bellary	(549) Sri G. Chemappa	Iron-ore	P. L.	470	30th May 1938	One year.
Do.	(550) Md. K. Basheer Sahib.	Manganese-ore	P. L.	15	6th May 1938	Six months.
Cuddapah	(551) Messrs. T. H. B. Tiffin & Co.	Barytes	P. L.	1325·48	28th June 1938.	One year.
Do.	(552) Sri A. Krishnappa	Iron-ore	P. L.	30	23rd November 1938.	Do.
Do.	(553) Sri Rao Bahadur B. P. Sesha Reddi.	Barytes	P. L.	11·60	4th December 1937.	Do.
Do.	(554) Syed Abdul Khader Sahib.	Do.	P. L.	9·45	22nd February 1938.	Do.
Do.	(555) Sri Rao Bahadur B. P. Sesha Reddi.	Do.	P. L.	4·64	21th January 1938.	Do.
Do.	(556) Messrs. Tiffin & Co.	Do.	P. L.	54·59	19th December 1937.	Do.
Do.	(557) Do.	Do.	P. L.	42·14	18th September 1937.	Do.
Do.	(558) Messrs. Putt & Rao.	Iron-ore	P. L.	64·40	28th January 1938.	Do.
Do.	(559) Sri A. Krishnappa	Do.	P. L.	13·00	22nd December 1937.	Do.
Do.	(560) Do.	Barytes	P. L.	38·08	22nd February 1938.	Do.
Do.	(561) Messrs. Tiffin & Co.	Do.	P. L.	10·01	16th June 1938.	Do.
Do.	(562) The Hon'ble Mr. Narayandas Girdhardas.	Galena	P. L.	31	23rd December 1938.	Do.
Do.	(563) Messrs. Tiffin & Co.	Barytes	P. L.	18·10	26th October 1938.	Do.
Do.	(564) Do.	Do.	P. L.	22·22	13th July 1938	Do.
Do.	(565) Sri Rao Bahadur B. P. Sesha Reddi.	Do.	M. L.	21·85	1st March 1938.	30 years.
Do.	(566) Messrs. Tiffin & Co.	Do.	M. L.	109·87	1st July 1938	Do.
Kurnool	(567) The Hon'ble Mr. Narayandas Girdhardas.	Lead, silver and zinc	M. L.	162	9th July 1938	10 years.
Do.	(568) Do.	Iron-ore and manganese-ore	M. L.	77·60	Do.	Do.
Do.	(569) Sri Rao Bahadur B. P. Sesha Reddi.	Barytes	M. L.	30·00	9th December 1938.	5 years.
Do.	(570) The Hon'ble Mr. Narayandas Girdhardas.	Diamond	P. L.	932·35	13th February 1938.	1 year.
Do.	(571) Sri Vishnu Nimbkar.	Oxide of iron	P. L.	51	21st October 1938.	Do.
Do.	(572) Sri B. Venkataswami Chetti.	Barytes	P. L.	10	14th October 1938.	One year.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool	(573) Sri P. Venkayya	Diamond	P. L.	54·91	2nd October 1938.	One year.
Do.	(574) Sri Rao Bahadur M. Venkatakrishnayya.	Do.	P. L.	33·86	21st September 1938.	Do.
Do.	(575) Abdul Nabi Sahib	Barytes	P. L.	11	8th November 1938.	Do.
Do.	(576) Sri Rao Bahadur B. P. Sesha Reddi.	Do.	P. L.	22	9th December 1938.	Do.
Nellore	(577) Sri Sanjivi Chetti	Mica	M. L.	83·02	2nd February 1938.	30 years.
Do.	(578) The Tellakodu Co., Ltd.	Do.	M. L.	19·72	Do.	9 years.
Do.	(579) Sri Gundra Chenchu Subba Reddi.	Do.	M. L.	18·80	18th February 1938.	30 years
Do.	(580) Sri P. Dasaradarama.	Do.	M. L.	58·92	17th March 1938.	Do.
Do.	(581) Do.	Do.	M. L.	35·35	7th March 1938.	Do.
Do.	(582) Sri Velur Sanjinappa Nayudu.	Steatite	M. L.	40	5th March 1938.	Do.
Do.	(583) Sri Aman Cherla Chengal Rao.	Mica	M. L.	27·25	17th March 1938.	Do.
Do.	(584) Sri B. Ramalingayya Reddi.	Do.	M. L.	1·21	29th April 1938.	Do.
Do.	(585) Sri T. Chenchayya Nayudu.	Do.	M. L.	4·44	13th June 1938.	Do.
Do.	(586) Sri K. Rami Reddi	Do.	M. L.	17·75	2nd May 1938	Do.
Do.	(587) Sri C. M. Guruda Chari.	Do.	M. L.	5·41	30th May 1938	Do.
Do.	(588) M. Dasaradarama	Do.	M. L.	4	14th May 1938	Do.
Do.	(589) Sri Putnam Muraswami.	Do.	M. L.	235·55	28th June 1938.	Do.
Do.	(590) Sri P. Subbarami Reddi and Sri V. Sundararami Reddi.	Do.	M. L.	106·09	26th June 1938.	Do.
Do.	(591) Sri P. Krishna Reddi and Sri S. Ramalinga Reddi.	Do.	M. L.	18·54	25th November 1937.	Do.
Do.	(592) Sri T. Sesha Reddi	Do.	M. L.	49·24	24th January 1938.	Do.
Do.	(593) Sri V. G. Krishna Rao and Sri C. Mastem Reddi.	Do.	M. L.	146·94	7th September 1938.	Do.
Do.	(594) Sri V. Sundararami.	Do.	M. L.	10·92	14th September 1938.	Do.
Do.	(595) T. Rami Reddi	Do.	M. L.	84	30th August 1938.	Do.
Do.	(596) Sri P. Subbarami Reddi.	Do.	M. L.	7	14th September 1938.	Do.
Do.	(597) Sri V. Sanjivappa Nayudu.	Do.	M. L.	16·10	18th October 1938.	Do.
Do.	(598) Sri B. Ramalingayya Chetti.	Do.	M. L.	7·14	23rd November 1938.	Do.
Do.	(599) Sri V. Sanjivi Chetti, Sri R. Sankara Reddi and Sri Y. Dasaradarama Reddi.	Do.	M. L.	3	10th August 1938.	Do.
Do.	(600) Sri B. Rami Reddi	Do.	M. L.	0·26	25th November 1938.	Do.
Do.	(601) Sri T. Chenchayya Nayudu.	Do.	M. L.	9·88	19th December 1938.	Do.
Do.	(602) Sri G. C. Krishna Reddi.	Do.	M. L.	19·03	23rd December 1938.	Do.
Do.	(603) Sri V. G. Krishna Rao.	Do.	P. L.	22·75	16th December 1937.	One year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

F

MADRAS—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(604) Sri Rao Sahib T. C. Dandayudam Pillai.	Mica	P. L. .	49·35	18th December 1937.	One year.
Do. .	(605) Sri Rao Bahadur B. P. Sesha Reddi.	Barytes . . .	P. L. .	4·35	1st February 1938.	Do.
Do. .	(606) Sri Vemana Ramachandrayya Nayudu.	Mica	P. L. .	27·20	23rd March 1938.	Do.
Do. .	(607) Sri Vallatur Venkata Subbayya Nayudu.	Do.	P. L. .	31·06	13th June 1938.	Do.
Do. .	(608) Sri Paderti Gopayya.	Garnet . .	P. L. .	40·05	25th June 1938.	Do.
Do. .	(609) Sri V. G. Krishna Rao.	Mica	P. L. .	6·30	17th August 1938.	Do
Do. .	(610) Sri M. Dasaradarami Reddi.	Do.	P. L. .	49·73	Do. .	Do.
Do. .	(611) Sri G. C. Krishna Reddi.	Do.	P. L. .	27·73	18th October 1938.	Do.
Salem . .	(612) Sri S. K. Ramachandar.	Mica, beryl and rock crystal.	P. L. .	16·55	10th March 1938.	Do.
Do. . .	(613) Do. .	Do. . .	P. L. .	4·94	16th May 1938.	Do.
Do. . .	(614) Do. .	Mica	P. L. .	44·91	Do. .	Do.
Tanjore	(615) Messrs. C. Manavalan and K. H. Chambers.	Black sand, ilmenite, monazite, zircon, rutile and garnet.	P. L. .	283·07	17th July 1938	Do.
Trichinopoly	(616) Messrs. Dalmia Cement, Limited.	Limestone . .	M. L. .	197·63	1st September 1938.	30 years.

NORTH-WEST FRONTIER PROVINCE.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kohat .	(617) Indo-Burmah Petroleum Co., Ltd., Rawalpindi.	Natural Petroleum .	P. L. . (Renewal).	3626·2	18th October 1935.	1 year.
Do. . .	(618) Do. .	Do. .	P. L. . (Renewal).	800	Do. .	Do.
Mardan	(619) Frontier Development Corporation, Ltd.	Marble	M. L. .	23·919	11th May 1938	10 years.
Do. .	(620) Do. .	Do.	M. L. .	13·519	Do. .	Do.
Sheikh Jana .	(621) Do. .	Do.	M. L. .	88·006	Do. .	Do.

ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Sambalpur .	(622) Babu Mani Mohan Ghosh.	Red Oxide of iron .	M. L. .	71·50	2nd March 1938.	5 years.
Do. .	(623) Mr. Manji Bechar	Alum	P. L. .	225	10th December 1938.	1 year.

PUNJAB.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Attock .	(624) The Attock Oil Co., Ltd., Rawalpindi.	Mineral oil . . .	P. L. .	7,800	8th September 1938.	1 year.
Do. .	(625) Do. .	Do. . . .	P. L. .	18,560	Do. .	Do.
Do	(626) Do. .	Do. . . .	P. L. .	16,000	14th November 1938.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

PUNJAB—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(627) Messrs. Wat Stone Lime Quarry, Ltd., and Pt. Gian Chand.	Coal	M. L. .	80	9th May 1938	30 years.
Do. .	(628) The Chakwal Brick Company, Chakwal.	Do.	M. L. .	183·6	1st May 1938	20 years.
Do. .	(629) Lala Sant Ram Kapur.	Do.	M. L. .	63·3	17th March 1938.	10 years.
Do.	(630) Do. .	Do.	M. L. .	94	1st March 1938.	10 years.
Do. .	(631) S. Jai Ram Singh	Do.	M. L. .	54·4	14th July 1938	25 years.
Do. .	(632) Messrs. Sundar Das and Sons and M. Allah Din.	Do.	P. L. .	145·5	15th May 1938	1 year.
Do. .	(633) S. Jai Ram Singh	Do.	P. L. .	110·4	25th March 1938.	Do.
Do. .	(634) Do. .	Do.	P. L. .	426·91	15th February 1938.	Do.
Do. .	(635) Lala Ram Autar .	Do.	P. L. .	61·47	1st March 1938.	Do.
Do. .	(636) Lala Sant Ram .	Do.	P. L. .	62	17th March 1938.	Do.
Do. .	(637) S. Jai Ram Singh	Do.	P. L. .	384	20th April 1938	Do.
Do. .	(638) Messrs. Chaman Lall Bhola and Sons.	Do.	P. L. .	120	19th April 1938	Do.
Do. .	(639) Lala Ram Autar	Do.	P. L. .	102·4	28th November 1938.	Do.
Mianwali .	(640) Lala Chuni Lal Kapur.	Do.	M. L. .	1,014·9	29th July 1938.	30 years.
Rawalpindi .	(641) The Attock Oil Co., Ltd., Rawalpindi.	Mineral oil . .	P. L. .	5,120	25th November 1938.	1 year.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

SUMMARY.

Province.	Prospecting Licenses.	Mining Lease.	Quarry Lease.	Total for each Province.
India—				
Ajmer-Merwara	35	6	..	41
Assam	16	1	..	17
Baluchistan	1	4	..	5
Bihar	12	11	..	23
Bombay	22	6	..	28
Central Provinces	324	66	36	426
Madras	43	33	..	76
North-West Frontier Province	2	3	..	5
Orissa	1	1	..	2
Punjab	12	6	..	18
Total of each kind and grand total .	408	137	36	641
Total for 1937 .	291	57	25	373
Burma 1938	469	64	..	533
1937	271	46	..	317

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 55.—*Prospecting Licenses and Mining Leases granted in Ajmer-Merwara during the year 1938.*

District.	1938.		
	No.	Area in acres.	Mineral.
		PROSPECTING LICENSES.	
Ajmer	6	13·66	Mica and beryl.
Do.	6	14·88	Mica, beryl and felspar.
Do.	1	1·26	Asbestos and kyanite.
Do.	6	22·74	Mica.
Do.	1	1·97	Muscovite.
Do.	1	1·98	Felspar.
Beawar	2	5·75	Mica and beryl.
Do.	12	209·09	Mica.
TOTAL .	35		
		MINING LEASES.	
Ajmer	2	8·74	Mica, beryl and felspar.
Do.	1	0·65	Mica and muscovite.
Beawar	1	6·56	Mica.
Do.	1	3·05	Mica, beryl and felspar.
Mansharpura Estate .	1	Not reported	Mica.
TOTAL .	6		

TABLE 56.—*Prospecting Licenses and Mining Leases granted in Assam during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES.		
Cachar	10	31,323	Natural petroleum including natural gas.
Lakhimpur	1	5,120	Natural petroleum.
Nongstoin State . . .	2	1,120	Sillimanite, corundum and all associated refractory minerals.
Sylhet	3	15,602	Natural petroleum including natural gas.
TOTAL .	16		
	MINING LEASE.		
Lakimpur	1	5,760	Natural petroleum.
TOTAL .	1		

TABLE 57.—*Prospecting Licenses and Mining Leases granted in Baluchistan during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSE.		
Loralai Agency . . .	1	5,760	Natural petroleum including natural gas.
TOTAL .	1		
	MINING LEASES.		
Quetta-Pishin Agency .	2	160	Coal.
Sibi Agency	2	160	Do.
TOTAL .	4		

TABLE 58.—*Prospecting Licenses and Mining Leases granted in Bihar during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES.		
Santal Parganas . .	8	4,516·4	Manganese-ore.
Do. . .	4	1,220·3	Chromite.
TOTAL .	12		
	MINING LEASES.		
Hazaribagh . . .	5	380·14	Mica.
Santal Parganas . .	3	103·88	Manganese.
Do. . .	3	14·92	Coal.
TOTAL .	11		

TABLE 59.—*Prospecting Licenses and Mining Leases granted in Bombay during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES.		
Belgaum	14	1,047·99	Bauxite.
Do.	1	13·97	China clay.
Kanara	6	3,095·15	Manganese-ore.
Bombay Suburban . .	1	4,775·3	Limestone, clay and gypsum.
TOTAL .	22		
	MINING LEASES.		
Broach and Panchmahals	1	3,356·57	Gold and silver.
Kanara	5	2,101·2	Manganese-ore.
TOTAL .	6		

TABLE 60.—*Prospecting Licenses, Mining and Quarry Leases granted in the Central Provinces during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES.		
Balaghat	61	4,069	Manganese-ore.
Betul	7	3,171	Coal.
Do.	1	90	Marble.
Do.	1	137	Graphite.
Do.	1	77	Building and marble stone.
Bhandara	37	2,902	Manganese-ore
Do.	1	184	Iron-ore.
Do.	2	194	Pottery clay.
Chanda	1	595	Mica.
Do.	1	65	Yellow ochre.
Do.	2	1,539	Coal.
Chhindwara	44	4,197	Manganese-ore.
Do.	8	1,712	Coal.
Drug	1	25	Lead and silver.
Hoshangabad	1	34	Clay.
Jubbulpore	1	832	Zeolites.
Do.	1	225	Coal.
Do.	5	130	Barytes.
Do.	7	1,311	Bauxite.
Do.	2	83	Manganese-ore.
Do.	5	177	Clay.
Do.	4	336	Soapstone.
Do.	1	99	Red ochre.
Do.	1	27	Red earth.
Do.	1	19	Hæmatite.
Nagpur	115	9,169	Manganese-ore.
Do.	3	58	Limestone.
Do.	1	21	Building stone.
Do.	1	634	Wolfram.
Do.	1	15	Red and yellow oxide.
Raipur	2	68	Limestone and building stone.
Do.	1	12	Building stone.
Yeotmal	2	44	Limestone.
Do.	1	151	Coal.
TOTAL	324		
	MINING LEASES.		
Balaghat	29	1,725	Manganese-ore.
Betul	1	343	Coal.
Bhandara	6	220	Manganese-ore.
Bilaspur	3	263	Limestone.
Chhindwara	5	4,559	Coal.
Do.	2	117	Manganese-ore.
Nagpur	19	811	Do.
Yeotmal	1	1,590	Coal.
TOTAL	66		

TABLE 60.—*Prospecting Licenses, Mining and Quarry Leases granted in the Central Provinces during the year 1938*—contd.

District.	1938.		
	No.	Area in acres.	Mineral.
	QUARRY LEASES.		
Betul	1	107	Red oxide and ochre.
Bilaspur	4	12	Limestone.
Chanda	1	11	Yellow ochre.
Do.	1	225	Iron ore.
Do.	1	122	Limestone.
Do.	1	105	Sand.
Drug	1	15	Flooring stone.
Jubbulpore	1	43	Red ochre and oxide of iron.
Do.	2	35	Limestone.
Do.	1	1	Yellow Fullers earth.
Do.	1	1	Stone.
Do.	6	8	Clay.
Nagpur	1	6	Limestone.
Do.	4	56	Building stone.
Do.	1	7	Clay.
Do.	1	22	Sand.
Do.	1	24	Boulders and murrum.
Raipur	1	3	Flooring stone.
Do.	1	7	Clay.
Do.	1	2	Limestone.
Do.	1	12	Building stone.
Yeotmal	3	15	Limestone.
TOTAL	36		

TABLE 61.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1938.*

District.	1938.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Anantapur	2	7,562·4	Gold.
Do.	5	386·69	Barytes.
Bellary	1	470	Iron-ore.
Do.	1	15	Manganese.
Cuddapah	10	1,536·31	Barytes.
Do.	3	107·40	Iron-ore.
Do.	1	34	Galena.
Kurnool	3	43	Barytes.
Carried over	26		

TABLE 61.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1938*—contd.

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES—*contd.*		
Brought forward	26	..	
Kurnool	3	1,021·12	Diamond.
Do.	1	51	Oxide of iron.
Nellore	7	217·12	Mica.
Do.	1	4·35	Barytes.
Do.	1	40·05	Garnet.
Salem	2	21·49	Mica, beryl and rock crystal.
Do.	1	44·91	Mica.
Tanjore	1	283·97	Black sand, ilmenite, monazite, zircon, rutile and garnet.
TOTAL	43		
	MINING LEASES.		
Anantapur	1	20	Barytes.
Cuddapah	2	134·72	Do.
Kurnool	1	162	Lead, silver and zinc.
Do.	1	77·60	Iron-ore and manganese-ore.
Do.	1	30·00	Barytes.
Nellore	25	989·56	Mica.
Do.	1	40	Steatite.
Trichinopoly	1	197·63	Limestone.
TOTAL	33		

TABLE 62.—*Prospecting Licenses and Mining Leases granted in the North-West Frontier Province during the year 1938.*

District.	1938. No.	1938. Area in acres.	1938. Mineral.
	PROSPECTING LICENSES.		
Kohat	2	4,426·2	Natural petroleum.
TOTAL	2		
	MINING LEASES.		
Mardan	2	37·438	Marble.
Sheikh Jana	1	88·006	Do.
TOTAL	3		

TABLE 63.—*Prospecting License and Mining Lease granted in Orissa during the year 1938.*

District.	1938.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSE.		
Sambalpur . . .	1	225	Alum.
TOTAL .	1		
	MINING LEASE.		
Sambalpur . . .	1	71·50	Red oxide of iron.
TOTAL .	1		

TABLE 64.—*Prospecting Licenses and Mining Leases granted in the Punjab during the year 1938.*

District.	1938.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Attock	3	42,360	Mineral oil.
Jhelum	8	1,412·68	Coal.
Rawalpindi . . .	1	5,120	Mineral oil.
TOTAL .	12		
	MINING LEASES.		
Jhelum	5	475·3	Coal.
Mianwali . . .	1	1,044·9	Do.
TOTAL .	6		

MINERAL CONCESSIONS GRANTED IN BURMA DURING 1938.*

The number of concessions granted during the year was 533, of which 384 were new prospecting licences, 85 were renewals of previously granted prospecting licences, 63 were mining leases and 1 was a renewal of a previously granted mining lease. The total number of concessions held during the year 1938 was 1,039 of which 342 were held under mining leases and 697 under prospecting licences. Details regarding the number of concessions classified according to the minerals for which they were granted are given below :—

	Prospecting licences.	Mining leases.
(a) *Tin*—		
(1) Issued during 1938	17	4
(2) Held during 1938	24	54
(b) *Wolfram*—		
(1) Issued during 1938	18	12
(2) Held during 1938	71	20
(c) *Tin and Wolfram*—		
(1) Issued during 1938	165	38
(2) Held during 1938	186	161
(d) *Tin, Wolfram and Gold*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	2	2
(e) *Tin, Wolfram, Lead, Gold and Silver*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	1
(f) *Tin, Wolfram, Gold, Molybdenite and Bismuth*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	1
(g) *Tin, Wolfram, Antimony, Lead and Silver*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	1
(h) *Oil-shale*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	1

* Taken from "Report on mining and mineral production in Burma for the year 1938".

	Prospecting licences.	Mining leases.
(i) *Antimony*—		
(1) Issued during 1938	4	*Nil*
(2) Held during 1938	10	1
(j) *Antimony and Zinc*—		
(1) Issued during 1938	*Nil*	1
(2) Held during 1938	*Nil*	1
(k) *Antimony, Copper and Lead*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	3	*Nil*
(l) *Iron Ore*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	1	10
(m) *Gold*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	2	*Nil*
(n) *Gold and Platinum*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	4	2
(o) *Gold, Silver and Platinum*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	1
(p) *Lead Oxide*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	1	*Nil*
(q) *Lead and Copper*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	1	*Nil*
(r) *Lead and Silver*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	3	*Nil*
(s) *Lead, Silver, Copper and Zinc*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	*Nil*	2
(t) *Lead, Silver, Wolfram and Antimony*—		
(1) Issued during 1938	*Nil*	5
(2) Held during 1938	*Nil*	5
(u) *Wolfram, Scheelite, Cassiterite and Molybdenite*—		
(1) Issued during 1938	*Nil*	1
(2) Held during 1938	*Nil*	1

	Prospecting licences.	Mining leases.
(v) *Coal*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	2	*Nil*
(w) *Galena*—		
(1) Issued during 1938	2	1
(2) Held during 1938	3	1
(x) *Manganese*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	1	*Nil*
(y) *Natural Petroleum (including natural gas)*—		
(1) Issued during 1938	53	1
(2) Held during 1938	86	51
(z) *All minerals*—		
(1) Issued during 1938	7	*Nil*
(2) Held during 1938	7	*Nil*
(aa) *All minerals except Tin*—		
(1) Issued during 1938	2	*Nil*
(2) Held during 1938	9	*Nil*
(bb) *All minerals except Oil*—		
(1) Issued during 1938	173	*Nil*
(2) Held during 1938	229	3
(cc) *All minerals except Precious Stones*—		
(1) Issued during 1938	*Nil*	1
(2) Held during 1938	3	1
(dd) *All minerals except Tin and Oil*—		
(1) Issued during 1938	16	*Nil*
(2) Held during 1938	23	*Nil*
(ee) *All minerals except Tin and Wolfram*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	2	*Nil*
(ff) *All minerals except Oil and Precious Stones*—		
(1) Issued during 1938	4	*Nil*
(2) Held during 1938	20	22
(gg) *All minerals except Tin, Oil and Wolfram*—		
(1) Issued during 1938	*Nil*	*Nil*
(2) Held during 1938	1	*Nil*
(hh) *All minerals except Tin, Oil and Precious Stones*—		
(1) Issued during 1938	1	*Nil*
(2) Held during 1938	3	*Nil*

Two mining leases for tin and three mining leases for tin and wolfram in the Mergui District were surrendered during the year.

THE CHROMITE DEPOSITS IN THE RATNAGIRI DISTRICT AND SAVANTVADI STATE, BOMBAY PRESIDENCY. BY L. A. N. IYER, M.A. (MADRAS), Ph.D. (LOND.), D.I.C., *Geologist, Geological Survey of India.* (With Plate 20.)

INTRODUCTION.

The chromite deposits in the Ratnagiri district and Savantvadi State, Bombay Presidency, have been known for some years and

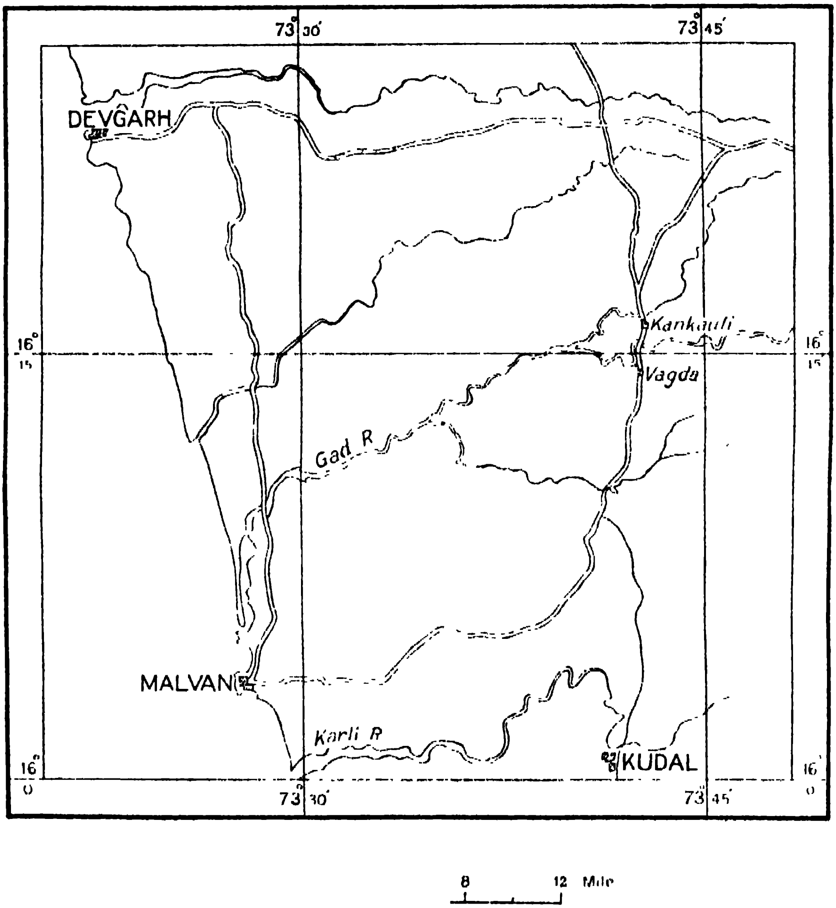


FIG. 1.

have received some attention recently. The writer was deputed to examine the occurrences of chromite and other minerals in this area during the field-season 1937-38 at the request of the Bombay Government, as the available information about them was meagre, though prospecting and mining leases had been taken up in these areas recently.

The chromite deposits are situated at two localities, near Kankauli (16° 16′: 73° 45′) on the bank of the river Janauli, and near Vagda (16° 14′: 73° 45′), south of the Gad river. Both places are accessible to the ports of Malvan (16° 4′: 73° 30′) and Devgad[1] (16° 22′: 73° 25′), which are connected by motorable roads. There is no good road connecting the chromite localities with the main road, but during summer bullock carts could travel across the fields. The Kankauli deposit has been taken up by Messrs. Oakley, Duncan and Co. of Bangalore under a mining and prospecting lease, and the Vagda deposit has been taken up by Mr. Sonavala of Bombay.

Previous literature.

The occurrences find mention in the Bulletin of the Imperial Institute, London, Vol. VIII, (1910), p. 401, and also in the Imperial Institute Monograph on chromium ore (1921), p. 18, which is quoted below.

> "In the Bombay Presidency, 60 miles from Ratnagiri, large outcrops of chromite occur associated with serpentine. Some of the outcrops are said to be 1,000 feet long and 300 feet wide, and specimens assayed 34 per cent. Cr_2O_3."

Dr. P. K. Ghosh of this department also visited the area recently. The results of his examination are embodied in the Director's General Report for 1933[2].

> "The deposit occurs as a roughly east to west dyke or vein, about half a mile in length, with a width varying from 30 to 36 feet, and intersecting the foliation of the older, pre-Cambrian gneisses and schists. It is also of pre-Cambrian age.
>
> The ore-body is associated with serpentine which appears now and then at the centre of the mass. There has been no separation of clean ore; instead the chromite occurs mostly as disseminated grains in serpentine and chlorite. Assays yielded 34 to 41 per cent. Cr_2O_3, so that unless the quality improved with depth the ore will not without concentration be of much value in normal times."

[1] Also spelt as Devgarh.
[2] *Rec. Geol. Surv. Ind.*, Vol. LXVIII, p. 30, (1933).

The results of Dr. P. K. Ghosh's investigations have also been published in the Bulletin of the Imperial Institute, Vol. XXXIV, No. 3, pp. 374-375, (July to September, 1936).

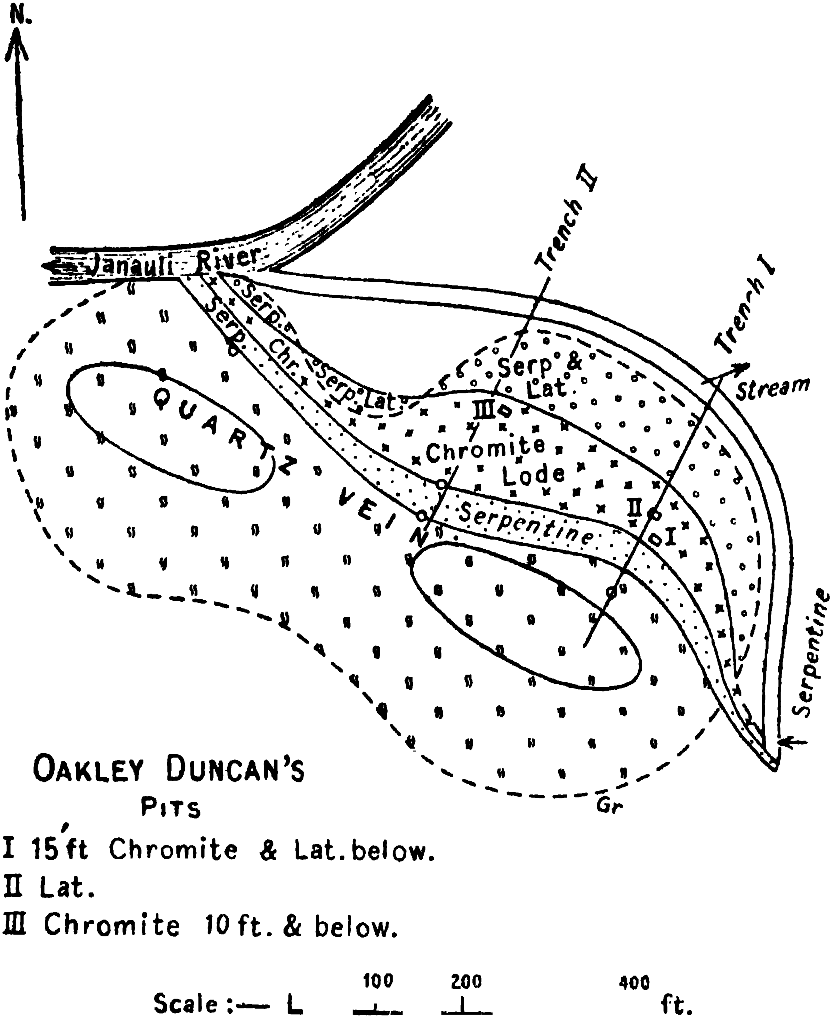


Fig. 2

Geology of the area near Kankauli and Vagda.

East of Kankauli, boulders of biotite-hornblende-granite are seen in paddy fields, with debris of banded quartzite of Kaladgi

age strewn over the ground. To the east of the chromite-serpentine exposure, granite again occurs along the stream, and a little further south Deccan trap covers the eroded surface of the pre-Cambrian rocks. East of the path to Janauli from Kankauli, a vein or dyke of quartz runs almost east to west for about 300 yards to the southern bank of the Janauli, where it takes a north-easterly turn. The quartz is very much fractured and jointed. A hollow in the middle of the quartz dyke divides the hill into two small knolls.

The strike of the chromite dyke is W. N. W. to E. S. E., and the dip is south. It is found on the top of the eastern knoll on its northern side, cutting across in a west-north-west direction, and pinching out in the Janauli stream. The strike of the serpentine is W. 10° N. in the stream. The exposure is 250-300 yards long, and east of the chromite hill the serpentine persists for another 100 feet.

The distance between the eastern and western knoll is about 50-60 feet, and the western knoll is 400 feet long and about 300 feet across. The chromite-serpentine lode swings off this hill to the river and across it, it is only about 10 feet broad in the river. The serpentine forms a wall and crosses the stream with the chromite, which is only about 5-10 feet broad here. Another small exposure of chromite is seen emerging in the angle between the Janauli and the smaller stream meeting it. Here serpentine forms the bulk of the exposure with the two thin bands of chromite.

The Chromite deposits at Vagda.

On the south bank of the Gad river, where the old and new roads to Malvan meet, and two furlongs south-east of this point, two parallel ridges running N. N. W. to S. S. E., are separated by a cultivated hollow. As one walks east from the road towards this area, rounded sandstone boulders of the Kaladgis and thin veins of quartz debris are seen. Further up, the quartz veins form the country rock or the ground is covered by gravel and soil where the quartz veins are absent.

The northern end of the western ridge is mostly of quartz but on the western side serpentine and quartz occur passing into serpentine, which continues south-south-east and also forms the eastern flank of the hill with some hornblende-schist. The chromite forms just a thin cover on the serpentine. Scuth of the point where the

chromite ends, the serpentine becomes continuous forming a ridge running S. S. E. An irregular oval patch of chromite in this area

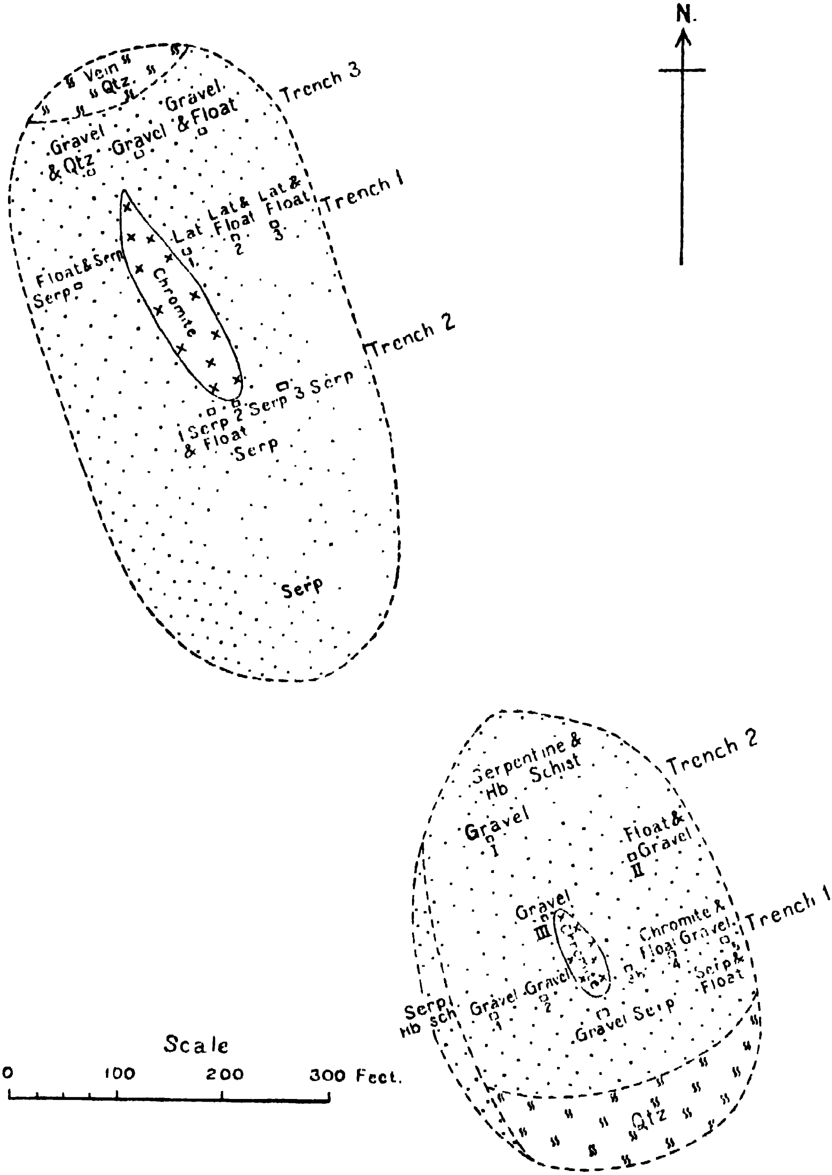


Fig. 3

forms a serrated ridge. The debris, forming 'float', produces an erroneous impression of the dimensions of the chromite lode. The serpentine dips in this area to the S. S. W. at 70-80°. On weathering it passes into laterite. The hornblende-schist, which is found on the eastern side of this ridge, presents a problem as regards its origin. It is difficult to decide whether it belongs to the ultra-basic suite or to a different intrusive.

A few yards east of the above is a second narrow ridge where also vein quartz occurs at the northern extremity. The main axis of this ridge is about 600-650 feet long and is mostly of hornblende-schist, which passes on the southern side to serpentine. East of this ridge a few granite boulders are present, beyond which Deccan trap flows occur. The top of this ridge is of hornblende-schist which becomes granular southwards and passes into serpentine.

The southern end of this hill is flat and serpentine occurs along the base both on the east and west as also on the south. A little distance to the south the presence of a vein of quartz and pegmatite proves that the chromite-serpentine lode is intrusive into the gneisses and schists. The serpentine on the flat hill passes into lateritic soil, and the ground is, as usual, strewn with chromite debris.

Petrology.

The chromite occurs as irregular veins or lenses in the serpentine. The mineral occurs in a matrix of chlorite, the ore being grey in colour. Amphibolite is at times associated with the serpentine. Two kinds of serpentine were noted. (i) Antigorite—the usual form, developed from olivine, is granular and massive with green colour and under the microscope shows the characteristic mesh structure; (ii) a fibrous form, apple green to jade green in colour. Actinolite has also been produced as a by-product of the serpentinisation.

The massive variety of serpentine is found with some calcite at the western end of the chromite exposure at Kankauli. It also carries some euhedral crystals of chromite along the meshes of the serpentine. Some of this serpentine was found to lie below the chromite.

The fibrous serpentine, or williamsite, is more in evidence on either side of the chromite lodes both at Kankauli and Vagda. At Kankauli it was seen in the Janauli stream, where it takes a

north-easterly bend (specimen 52/665 of the serpentine), east of the chromite exposure. It is usually a massive grey rock, made up of fibrous serpentine, the bundles of fibres running in different directions, and generally showing variable birefringence with also the development of actinolite. In some places pure actinolitic rocks were found, as near Vagda. The actinolite does not show any appreciable pleochroism, and carries small quantities of chromite.

In the Vagda area, south of the Gad river, the fibrous serpentine shows the usual characters, and forms the country rock for the chromite. Hornblende-schist occupies the northern part of the eastern ridge. It is a medium-grained, dark, granular rock, mostly made up of hornblende, and has a slight schistosity.

The boundaries of the chromite lodes with the serpentine are sharp, but as the serpentine is frequently lateritised the walls are usually covered. The gangue material consists of two varieties of chlorite having different refractive indices and birefringence. For one variety the refractive index had a value between 1·580 and 1·583, corresponding to that of chlorite, the other had a value between 1·605 and 1·610, corresponding to prochlorite. The quantity of chlorite and chromite varied in the different specimens.

Chromite. The chromite grains occur in varying sizes. The maximum diameter was found to be 3·2 mm, and the average size varied between 1 and 2 mm. They are mostly euhedral to subhedral, only a small proportion being anhedral. In thin section the crystals show various forms, square, rectangular, lozenge-shaped, etc., according to the direction in which the crystals have been cut. Inclusions of the matrix are also present in the chromite grains. The chromite grains also occasionally send out tongues or projections to meet other crystals. Some of the crystals show rounding and corrosion of the margins by the matrix. Some crystals have been broken up, others show a continuous growth, one crystal touching the other to form linear patches as a string of beads. At times the form varies from euhedral to anhedral where the corrosive effect of the hydrothermal fluids was more effective; the crystals have also been fractured and corroded, resulting in very irregular margins, and also got carried in the current and appear to have been affected by the flowing matrix when the latter was in a fluid condition. Most of the chromite is dark, but some show a deep brown to red colour.

The chlorite matrix has a little brownish limonitic stain. This stain is more common around the chromite grains. The matrix is usually subordinate in quantity to the chromite, which forms more than 60 per cent. of the section. There is considerable variation in the amount of matrix in different parts of the ore. The chlorite matrix also shows flow movements since the crystals of chlorite bend round the chromite grains. The pressure from the sides, when the magma was intruded along channels bounded by walls might also have contributed to this structure. In some places a crowding of the crystals is also present. Slide, 26·136 shows equidimensional grains mostly euhedral, with various sections of the octahedron. The matrix sends out tongues into the chromite. Corrosion and fracturing are present. In slide (26·137) the different sizes of crystals are more pronounced. They vary from quite large to microscopic grains. Some of the crystals are fractured and veins of the matrix occupy the cracks. Chromite also sends tongues into the matrix. Margins are rounded, at times and some crystals show continuous growths. In slide (26·138) the corrosion of the crystals and the flow movement in the matrix are more pronounced. The crystals have been corroded to a greater extent on the margin and form continuous strings. Chromite is very abundant in this section. In slide (26·139), the matrix is much less than in the last, the crystals being more fractured. Crowding in continuous streams is also noted. In slides (26·140—26·142) the bead structure is more in evidence, and the continuous growths of crystals run in different directions.

Dr. J. A. Dunn examined a few polished sections of the chromite ore and found the following additional facts :—

Polished Sections.

In polished sections the chromite grains sometimes show slight gradation in colour. Inclusions of the groundmass are often arranged along the octahedral direction in the crystals. Minute thread-like veinlets of hematite are commonly present and very rarely small grains of hematite. A very little magnetite occurs occasionally but is commonly replaced by hematite. Minute veinlets of limonite also occur. In most of the sections there is fine pyritic dust (mainly chalcopyrite and pyrite) scattered within the matrix.

Genesis of the Chromite Ore.

Until recently chromite was regarded as a product of magmatic segregation in such ultrabasic rocks as the peridotites. Vogt[1] has described the succession in Norwegian deposits as chromite, olivine, and soda-lime felspar. In all cases the chromite appeared to be the earliest consolidated constituent. A similar view has also been held about the origin of the chromite deposits of Baluchistan and Singhbhum district in Bihar by Sir L. L. Fermor[2]. Recent investigators feel that there has been an over-emphasis on the magmatic segregation hypothesis on the origin of chromite. E. Sampson[3], who has made a very detailed study of this subject, considers four lines of evidence, which are useful to decipher the origin of chromite.

"(1). Veins of chromite cutting rocks whose magma may have furnished the chromite; (2). structural relations of chromite to other minerals as revealed by the microscope; (3). association of chromite with minerals known to form at a late stage; (4). a study of the composition of the chromite as compared with the gross composition of the associated rocks".

Pursuing his studies on the above lines, he concludes that although much chromite may crystallise at a very early stage, a substantial amount of the constituents of the mineral passes into a residual solution, and even into a highly aqueous solution capable of considerable migration.

The same question has been discussed by Clarence S. Ross, E. Sampson and J. T. Singewald[4]. Ross, under the caption "Is chromite always a magmatic product?", mentions from his study of North Carolina dunite bodies, which are little altered and which present good opportunities for the study of the mineral relations, that a part of the chromite is later than the dunite and suggests a hydrothermal origin. Here most of the chromite grains are anhedral to subhedral and a few euhedral. Cutting the dunite, small veins containing anthophyllite, tremolite, biotite, chlorite, serpentine, etc., typical mineral assemblages of hydrothermal processes are present. Another point in evidence, in support of the above theory

[1] W. Lindgren: Mineral Deposits, 4th Edn., p. 784, (1933).

[2] "Some Problems of Ore genesis in the Archæans of India. *Proc. A. S. B.*, Vol. XV, *N. S.* pp. clxx-cxcv, (1919).

[3] E. Sampson: May Chromite crystallise late? *Economic Geology*, Vol. XXLV, pp. 632-641, (1929).

[4] "Is chromite always a magmatic product?", C. S. Ross; Discussion—J. T. Singewald, *Economic Geology*, Vol. XXLV, pp. 642-649, (1929).

is that the silicates of the normal dunite contain no chromium, but the websterite and later hydrothermal minerals in the dunite do, thus showing that chromium was present in the material that crystallised into the websterite and possibly in hydrothermal solutions. J. T. Singewald concludes the discussion saying that the chromite lines up with the oxide ores in giving evidence of the activity of mineralisers in their deposition and that they do not represent solely a direct segregation of the first product of crystallisation from a molten magma.

He further says, "The evidence points strongly to the conclusions that when ore minerals separate from a magma as the earliest constituents to crystallize, they are likely to constitute but accessory minerals of the host rock, and that in these cases in which the metallic constituents of the magma have been locally concentrated to form masses of sulphidic and oxidic ores of economic importance, mineralizers have been an effective agent in segregating these minerals into the residual magma fluid. Or expressed in other words, ore deposits have generally resulted only when mineralizers have retarded the early crystallization of the ore minerals, thereby facilitating the retention by the residual magma fluid and their concentration within it. The highly mobile and liquid metalliferous magmatic extracts had the power of penetrating the rock-forming silicates which had in the meantime crystallized, and replacing them with the ore minerals, giving rise to ore bodies of such size and richness as to make workable deposits of the metals".

Lloyd W. Fisher[1], pursuing the subject of the origin of chromite deposits after a very detailed study, has discovered three distinct periods of crystallisation of chromite; 1. Chromite of the early magmatic period is the first mineral to crystallise—an overlap of the periods of crystallisation of chromite and olivine is often noted; 2. chromite of late magmatic period is later than the groundmass minerals and occurs in zones of crushed olivine, in cleavages of the cleavable minerals and as replacements of the earlier pyrogenic silicates of the groundmass; 3. chromite of hydrothermal period is definitely later than the pyrogenic silicates and is associated with deuteric minerals; the chromite of this period was formed from either early or late hydrothermal solutions.

Fisher says that much of the chromite is of primary crystallisation and that it is both of early and late magmatic origin. There is evidence of both solution and redeposition of this chromite by hydrothermal processes. It is difficult to draw a sharp line between deposits that are strictly magmatic segregations and those that have been formed largely by hydrothermal solutions.

[1] Lloyd W. Fisher: "Origin of Chromite Deposits". *Economic Geology*, Vol. XXIV, pp. 691-721, (1929).

He comes to the final conclusion, "the notion that chromite deposits have originated through primary crystallization '*in situ*' has been greatly over-emphasized—chromite of late magmatic period is of much greater importance than that of early magmatic period. Hydrothermal solutions causing serpentinisation have played an important role in the formation of chromite deposits by dissolving magmatic chromite and redepositing it with the hydrothermal silicates".

E. Sampson[1] presents new evidence for late chromite forming solutions and advocates a classification of chromite occurrences into three rather sharply defined groups, essentially similar to Fisher's view, (1) Chromite formed earlier than olivine or contemporaneously with it and in part included in olivine grains, (2) chromite formed at a late magmatic stage and crystallising with the last truly magmatic silicate, commonly either bronzite or plagioclase, (3) chromite formed by hydrothermal solutions for the most part immediately preceding or contemporaneous with intense serpentinisation.

He also agrees with Singewald and Fisher that chromite formed at an early magmatic stage does not occur in sufficient concentration to form ore, and where it occurs in workable concentration, some process other than unmodified accumulation of early formed crystals has been effective.

Again, in his study of the chromite deposits of South Africa, Sampson[2] mentions that chromite in such magmatic deposits crystallises with the latest silicate minerals rather than with the earliest, and that differentiation may concentrate chromium in a residual magma.

Sampson also considers the magma, that yields chromite bearing rocks by magmatic differentiation, a solution in a narrow sense, which owed its liquidity to high temperature and its volatile contents; and that the mineralisation is well towards the hydrothermal stage in which the solution owes its fluidity to volatiles than to high temperature. He finally concludes that chromite is strongly concentrated in the residual magma.

Regarding the Ural deposits of Russia, J. E. Spurr[3] is of the opinion that the chromite is of later crystallisation than the olivine.

[1] E. Sampson: "Varieties of Chromite Deposits", *Economic Geology,* Vol. XXVI, pp. 833-839, (1931).

[2] E. Sampson: "Magmatic Chromite Deposits in Southern Africa". *Economic, Geology,* Vol. XXVII, pp. 113-144, (1932).

[3] J. E. Spurr: "The Ore Magmas", p. 580, (1923).

In a recent study of the Saranovskya Chromite deposits, Northern Urals,[1] it has been found that the sequence of crystallisation of the peridotite is olivine, chromite, pyroxene. The chromite deposit of this area is probably of magmatic origin and syngenetic with the enclosing rocks.

The above views clearly indicate that magmatic segregation alone cannot produce rich deposits of chromite and that a certain amount of the mineral passes into a residual solution. The important suggestion is that part of the chromite is later than the olivine and is perhaps of a hydrothermal origin. The agency of mineralisers has also been invoked. Chromite of late magmatic origin is considered more important than chromite of early magmatic period. Finally a differentiation of the ultrabasic magma into a chromite-poor fraction and a chromite-rich fraction is postulated. The latter forms a residual magma and is intruded into the former.

In the microsections of chromite from Kankauli and Vagda, a large percentage of the crystals are euhedral with definite crystal outlines, a smaller percentage of subhedral grains, and very little of anhedral grains. But the crystals have been to some extent altered subsequently as seen in the fracturing, rounding of corners, and in the margins corroded and rendered irregular. The chromite has been partly removed in solution and used in connecting up the crystals with one another; these changes are clearly due to the action of the molten medium in which the crystals were carried. The corrosion is greater in some sections. These alterations show that part of the chromite was being dissolved by the molten material, which has crystallised as the matrix, and which was hydrothermal in part. The chromite, forming lenses or pockets in serpentine, shows that it was intruded into it. Thus it seems that these chromite deposits are also not the result of one process alone, but belong to magmatic and early hydrothermal. If it were due only to hydrothermal origin the crystals would have been mostly or entirely anhedral. The chromite forming marked veins in the serpentine shows that it was a differentiated magma richer in chromite and the evidence for the action of hydrothermal processes is the mineral assemblage of serpentine, actinolite, tremolite and chlorite in these rocks. Its magmatic origin in part is supported by the euhedral shapes of most of the crystals of chromite.

[1] The International XVII Geological Congress, "The Uralian Excursion, Northern part," pp. 29-32, (1937).

Chemical Composition of the chromite ore.

Thirteen samples of chromite were collected from the two localities from different parts of the two exposures and about 20 pounds of the ore were taken in each case from different blocks of ore to begin with; this was broken to small pieces, and then quartered in the usual manner. The analyses were made in the Laboratory of the Geological Survey and the following are the results:—

1. Kankauli—

	I.	II.	III.	IV.	V.	VI.	VII.
Cr_2O_3—per cent. .	36·49	35·26	33·93	35·28	31·63	28·27	33·03

I. East end of the exposure.
II. Near top of the exposure near Oakley Duncan's pit 1.
III. Bottom of trench 1.
IV. Near bottom of western trench in Oakely Duncan's pit 3.
V. Near western end of eastern hill.
VI. From Janauli stream.
VII. West end of exposure, western hill.

2. Vagda—

	VIII.	IX.	X.	XI.	XII.	XIII.
Cr_2O_3—Per cent.	36·92	36·37	39·30	33·43	39·04	37·52

VIII. Top of exposure on the first trench.
IX. 3rd pit in trench 1.
X. 2nd pit.
XI. Pit at 63 feet on west side of the axis on trench 1.
XII. Eastern hill, Vagda.
XIII. Fifty yards west of V.

Full analyses of two samples of the chromite ore from the Kankauli area (I and V) and two samples from the Vagda area (X and XI) are as follows:—

	I.	V.	X.	XI.
	%	%	%	%
SiO_2	7·36	9·28	4·12	9·21
Fe_2O_3	23·73	26·20	24·60	25·40
Al_2O_3	11·40	13·60	12·02	12·60
CaO	*Nil*	*Nil*	*Nil*	*Nil*
MgO	15·35	17·02	15·64	16·29
Cr_2O_3	36·40	31·63	39·30	33·43
	94·33	97·73	95·68	96·93

The present estimate of ore reserves in the two localities amounts to about 67,000 tons calculated at 12 cubic feet per ton on a very conservative basis assuming a depth of 10-15 feet. The Vagda ores are decidedly richer than the Kankauli ores, but the ore reserve is very limited. The Cr_2O_3 percentage of the ores varies normally from above 30 per cent. to 39 per cent. although one analysis showed below 30 per cent. Dr. M. S. Patel[1] of Bombay has worked out a method by which concentration of the ore with 50 per cent. Cr_2O_3, 25 per cent. FeO and 2 per cent. SiO_2 could be effected, but still the high iron content is an obstacle in the marketing of the concentrate. He is of the opinion that by reducing the iron oxide to 14 or 15 per cent. and by briquetting the concentrate, it might be possible to find a market for it.

[1] M. S. Patel: "The Possibility of the Utilisation of low grade Chrome ore in the Ratnagiri district and Savantvadi State", Proceedings of the 24th Indian Science Congress, Hyderabad, p. 240, (1937).

THE MINERAL RESOURCES OF THE CENTRAL PROVINCES AND BERAR. BY M. S. KRISHNAN, M.A., Ph.D., A.R.C.S., F.N.I., *Geologist, Geological Survey of India.* (With Plate 21.)

I.—INTRODUCTION.

General Geology.

The geological formations hitherto identified in the Central Provinces are shown in the following table in the order of increasing antiquity, the Dharwarian formations being the most ancient rocks known therein:—

Alluvium	Newer. Older.
Laterite.	
Deccan trap with Inter-trappeans.	
Lameta and other Infra-trappean rocks.	
Gondwana	Upper Gondwana. Lower Gondwana.
Purana	Upper Vindhyan. Lower Vindhyan (with ? Sullavai series). Cuddapah (including the Bijawars and the Penganga series).
Archaean	Pegmatites, granites, gneissose granites and basic intrusives. Schistose gneisses. Dharwarian formations—including Sausar series, Sakoli series, Chilpi Ghat series, Sonakhan beds, Sonawani series, etc.

The foundations of the province are, of course, constructed of the various Archæan formations, which are profusely and conspicuously exposed over a large portion of the province and build up many of the hill ranges. Furthermore, the structure of the Archæan complex has to a large extent determined the disposition of the later geological formations. In the northern portions of the province the average direction of the Archæan fold axes is E. to E.N.E., this being also the strike of the most important orographical feature, *viz.*, the Satpura range, built of Archæan rocks, covered at intervals

* The original article on this subject was written by Dr. (now Sir) L. L. Fermor in 1918 and revised by him in 1927. It has been thoroughly revised and brought up to date, in 1939, by Dr. M. S. Krishnan.

by the lavas of the Deccan Trap formation, and extending as a geological entity at least as far east as Korea State and probably as far as Ranchi. Speaking generally, the Satpura range separates the drainage of the Narbada and Son rivers on the north from that of the Godavari and Mahanadi on the south. The general strike of the Bijawars, Vindhyans and Gondwanas, as well as the alignment of the Narbada alluvial valley, also conforms to this direction. In the southern portions of the province the average direction of the Archæan fold axes tends to be N.N.E., *i.e.*, parallel to the Eastern Ghats, and certain Vindhyan and Cuddapah ranges also conform to this strike.

The north-eastern and south-western margins of the province are, however, bounded by terranes with a totally different strike, *viz.*, N.W., or at right angles to the average Archæan strike. This strike is exhibited by the Rampur (Raigarh-Hingir) coalfield on the north-east and by the Wardha valley and Godavari valley coalfields in the south-west, with, in the latter case, belts of Lower Vindhyan and Cuddapah rocks of the same average strike. Of a different type is the structure of the widespread of Cuddapah rocks forming the gently dipping Chhattisgarh basin.

These three strike directions are found converging in Bhandara, where they tend to be slightly convex towards each other and towards the centre.

The widespread flows of the Deccan Trap occupy nearly the whole of Berar, as well as wide stretches of the Satpuras, and give rise to the plateaus known as *pats* in Sirguja and Udaipur; this formation appears also as intrusive dykes and sills in various parts of the province, particularly in Korea State, where the dykes show an E.N.E. trend and where there is also an enormous doleritic sill intrusive in the Gondwanas and extending for many miles to the west into Rewah State in Central India. Similar features are seen in the Narsinghpur district and the adjoining parts of the Satpuras. Immediately underlying the traps in many places are various Infra-trappean rocks, some of which (the limestones) are at least partly due to the replacing action of waters derived from the trap upon underlying gneisses and other rocks, whilst others are sedimentary sandstones and clays of Upper Cretaceous age. The Deccan trap is apparently horizontal, but careful surveys show that there have been widespread post-trappean earth movements, causing gentle warping and dips and sometimes faults of

considerable magnitude. Capping the trap in many places, *e.g.*, in Seoni, Balaghat, Mandla, and on the *pats* of Sirguja and Udaipur, are roughly horizontal sheets of laterite occurring at altitudes of 2,000 to 3,500 feet above sea-level, and often containing deposits of good bauxite.

The majority of the rivers are bordered by strips of alluvium, amongst which two divisions may be detected: an older (probably Pleistocene) alluvium often rich in kankar, and now suffering denudation, in consequence of slight earth movements; and a newer (often darker) alluvium in process of formation at the present day. The widespread older alluvium of the Narbada and the Purna rivers appears to occupy basins formed as the result of gentle post-Deccan trap warping of the Peninsula along an axis having a N.N.W. alignment. Finally, resting upon all the geological formations are the recent soils, varying greatly in character and fertility according to the underlying formation in a large measure and ranging from the light sandy soils so often found on the crystalline rocks to the heavy black cotton soil characteristic of Berar and usually associated with the Deccan trap.

Geological occurrence of mineral deposits.

Although the rules for the grant of licenses to prospect for minerals and of mining leases do not (Mining Rule 5) "apply to minor minerals, such as slate, building stone, limestone and clay, the extraction of which will continue to be regulated by such separate rules as the Local Government may lay down in accordance with local circumstances and requirements," it is, nevertheless, convenient to refer to such substances in an account of the mineral wealth of the province. In fact such 'minor minerals' are becoming increasingly important at the present day and may even play a dominant role in the industry of a region. These mineral resources might be discussed in two ways--either according to their mode of geological occurrence, or in alphabetical order. For general purposes the latter is the more convenient and will be followed here; but, in order to give an idea of the relative value of the various formations as sources of mineral wealth, the following list has been compiled, showing the mineral substances of possible economic value known to exist in each formation. Those substances that have proved in the past, or are likely to prove in the near future, to be of considerable economic value, are shown in italics. From this list it will be seen that the most important

formations from the mineral point of view are the Dharwars, with their deposits of manganese-ore, iron-ore, steatite, red ochre and dolomite; the Gondwanas, with their stores of coal, fireclays and pottery-clays; the laterite, with its bauxite and building stone; and the alluvium with its supplies of brick-clays and kankar. Excellent building stones may be obtained from almost all the formations, as well as materials for the manufacture of cement, particularly in the Lower Vindhyans and Cuddapahs; and many minor mineral products may be developed in the future. Unfortunately, none of the pegmatite veins (with mica, quartz, and rose quartz) or mineral veins (with copper, lead, silver, wolfram, fluorspar, and barytes) hitherto discovered have proved to be of much value.

Mineral deposits found in the different geological formations.

Alluvium.—*Brick-clays, kankar,* salt, gold.

Lateritic Formations—

Laterite.—*Bauxite, building stone,* pyrolusite; *iron-ore;* diamonds.

Lateritoid.—*Iron-ore,* manganese-ore, ochre.

Deccan trap.—*Building stone* (basalt), agate, carnelian, jasper, opal, rock-crystal, *soda* (*trona*), mineral waters, Iceland spar, zeolites.

Infra-Trappean ("Lameta").—Limestone, manganese-ore.

Gondwana—

Upper.—*Pottery clay,* fireclay, coal, jasper pebbles.

Lower.—*Coal, fireclay, sandstone,* pottery clay, iron-ore.

Vindhyan—

Upper.—*Sandstone,* limestone, lithographic stone, manganese-ore, lead-ore.

Lower.—*Limestone, fuller's earth, shale,* sandstone, diamonds.

Bijawar.—Limestone, sandstone, jasper, iron-ore, lead-ore, silver.

Cuddapah.—*Limestone,* lithographic stone, sandstone, lead-ore.

Pegmatites and mineral veins cutting Archæans.—Mica, quartz, rose quartz, fluorspar, barytes, wolfram, and ores of copper, lead, silver, and gold.

Granite.—*Building stone.*

Gneiss.—*Building stone.*

Dharwarian (including Sausar series, Chilpi Ghat, and Sonakhan beds, etc.)—*Manganese-ore, iron-ore, limestone, dolomite, marble, ochre, steatite,* asbestos, jasper, garnet, opal, spinel.

The relative importance of the various mineral industries hitherto
tion figures given in the

Mineral production of the Central Provinces

—	Average 1909-13.	Average 1914-18.	Average 1919-23.	Average 1924-28.
Asbestos	(1910) 3	(*a*) 10	(*a*) 11	(1924) 20
Bauxite	449	939	2,163	2,371
Clay	17,382	39,768	51,939	30,638
Coal	227,960	327,733	585,026	684,400
Corundum	—	(1918) 80	—	(*c*) 11
Fuller's earth	100	196	158	(*b*) 47
Graphite	—	—	(*a*) 24	—
Iron-ore	2,612	(1915) 7,476	7,159	14,444
Laterite	—	16,445	—	(1928) 681
Lead-ore	—	(*b*) 5	(*a*) 1	—
Lime	—	—	—	(*c*) 237
Limestone and kankar	79,816	95,669	206,486	439,173
Manganese-ore	488,485	(1916)495,880	505,402	660,550
Marble	—	143	—	—
Ochre	258	209	(*b*) 676	450
Soda salts	—	—	(1923) 600	(*c*) 51
Steatite	476	1,527	1,183	1,648
Wolfram	(Total) 1·3	(1916) 1·3	—	—

(*a*) Average of 2 years.
(*b*) Average of 4 years.
(*c*) Average of 3 years.

established in the Central Provinces can be judged from the produc-
following table :—

from 1909 to 1937. (In long tons.)

Average 1929-33.	1934.	1935.	1936.	1937.	1938.
—	—	—	—	—	—
2,312	18	7,635	3,644	9,558	4,634
54,602	51,739	37,962	43,599	47,967	(*f*) 60,252
1,101,323	1,842,492	(*e*) 1,526,690	(*e*) 1,507,982	(*e*) 1,504,159	(*e*) 1,658,626
—	—	—	—	—	—
35	25	44	—	45	58
—	90	406	237	—	20
797	898	800	549	354	611
2,901	8,854	—	75	65	48
—	—	—	—	—	—
—	—	—	—	—	—
431,730	472,717	537,874	472,810	607,608	551,978
316,533	186,025	385,179	568,806	695,177	646,465
—	—	—	—	—	—
3,204	4,714	3,207	1,804	2,455	2,924
(*d*)	—	—	—	—	—
1,090	1,867	2,821	1,907	2,111	2,189
—	—	—	—	—	—

(*d*) Not available.
(*e*) Excludes production in Korea and Raigarh States.
(*f*) Includes 4,439 tons of 'yellow clay'.

To all students of the mineral resources of India La Touche's "A Bibliography of Indian Geology and Physical Geography with an Annotated Index of Minerals of Economic Value," issued by the Geological Survey of India in two parts in 1917 and 1918, respectively, must prove an indispensable work of reference; and in compiling the following account of the mineral resources of the Central Provinces, this work and the Quinquennial Reviews of Mineral Production in India (Vols. LVII, LXIV and LXX of the *Records of the Geological Survey of India*) have been freely drawn upon. In this account the original papers are not referred to in detail, as the full references can usually be obtained in La Touche's Bibliography. But a bibliography of the more important papers dealing with the mineral resources of the Central Provinces is appended to this note.

II.—MINERAL DEPOSITS.

Abrasives.

Quartzites and sandstones among rocks, and corundum and garnet among minerals, are abrasive materials. The quartzites in the Archæan formations and Cuddapahs and sandstones in the Purana formations and Gondwanas can be used for this purpose. Corundum is produced in a small way from the sillimanite and corundum bearing schists in Bhandara, but the deposits are small. Garnets are abundant in the garnetiferous mica-schists of the Archæan formations in Chhindwara, Nagpur, Balaghat, Bhandara and other districts.

Aluminous Refractory Materials.

In a small hill near Pohra village, about 13 miles west of Bhandara town, there are sillimanite-bearing mica-schists and fine grained tourmaline-rock. Workable sillimanite occurs in a massive form in the latter, as veins and replacement bodies up to six feet across. Corundum is also found here and has been worked in a small way for several years.

Sillimanite occurs in quartz schist N. E. of Khawasa (21° 42′: 79° 26′) as a thin band which can be followed for 1½ miles along the strike. The proportion of quartz is too high for working this as a source of sillimanite.

Unimportant deposits of corundum have also been found associated with sillimanite west of Keriapal (18° 18′: 81° 32′) in the Sukma tahsil of Bastar State.

Kyanite occurs in muscovite-schists in the Bhandara district near Dighori (20° 53′: 79° 55′) and between Dahegaon (20° 48′: 75° 55′) and Murjar (20° 53′: 79° 55′), but the rock is not rich enough in the mineral to be exploited for the latter.

Aluminium-ore (Bauxite).

Some years ago it was discovered that many of the lateritic deposits of India are highly aluminous, such aluminous varieties being identical with bauxite. Field-work carried out since 1903 by the officers of the Geological Survey has revealed the existence of extensive deposits of this material in various parts of India, and chemical investigation in the Geological Survey Laboratory and at the Imperial Institute has shown that certain of the Indian bauxites compared very favourably with the Irish, French and American bauxites. A special survey of the bauxite deposits of India was carried out soon after the War and the results have been published in *Memoirs, Geological Survey of India*, Vol. XLIX, Part 1.

Bauxite and aluminous laterite occur also in Bombay, Central India, Rajputana, Central Provinces, Bihar and Orissa.

Amongst the richest areas in the Central Provinces are the Baihar plateau in the Balaghat district and near Katni in the Jubbulpore district. Mandla and Seoni districts have also some good deposits.

The deposits in Jubbulpore are near Mahgawan, Dhangawan, Amochh, Chhapra, Sleemanabad, Niwar, Tikaria, Kusmi, Bargawan to Tikuri and Flag Staff Hill and other places. The quality of the material can be gathered from the following table:

——	Range.	Average of better grades.	Best grades. 1	2	3
SiO_2	1—20	2·5	1·10	1·20	0·38
TiO_2	5—11	8	8·75	7·01	11·61
Al_2O_3	40—65	60	61·30	60·49	65·48
Fe_2O_3	2—8	3—4	2·50	2·50	3·77
Moisture	0·3—1·5	0·5	0·01	0·27	1·06
Combined water	19—29	26	25·55	28·53	18·32

In Balaghat the principal occurrences are:

(1) On the ridge west of the Uskal River overlooking the Balaghat plain.
(2) The Laughur area between the Uskal and Nahara rivers.
(3) The main watershed of the Baihar uplands, and
(4) The Topla highlands forming the catchment area of the Halon river.

There is no good development of bauxite in the first area, whereas the second contains good material. The bauxite on Wajiri hill, at Pachama below the scarp of Gad Dadar and on the Sarad Dadar, contains 52 to 58 per cent. alumina. In the third area (Baihar watershed) also there is much good laterite, the following representing the range of the constituents (19 analyses):

	Per cent.
Alumina	48—64
Ferric oxide	2·5—17
Titania	4—11
Silica	Up to 3·5

In Mandla there is laterite in the southern and south-eastern areas around Chilpi Ghat, on the watershed between the Burmer, Chikrar and Siuni rivers, and on the Satpura scarp between Sontirath and Amarkantak. Some of these apparently contain good bauxite. A thin strip of laterite is found in the district along the scarp of the Maikala Range, some of the material near Amarkantak being known to analyse over 60 per cent. alumina.

In recent years some deposits with 60 per cent. of alumina have been found to occur near Bhabei (21° 31′ : 80° 45′) and further south in Nandgaon State. It occurs as bands and patches in laterite overlying shales, epidiorites and jaspilites.

Bauxite is the chief raw material used in the extraction of aluminium metal by electrolysis. Indian bauxite is nowadays used in decolorising petroleum, and removing sulphur compounds therefrom, because of the peculiar absorbent property of the colloidal constituents in the mineral. It also finds application in the manufacture of cement and refractories and abrasives. With the development of transport facilities and of the water power resources of the Province for the production of very cheap electricity, it should be possible to encourage the establishment of an aluminium industry.

Asbestos.

Asbestos occurs with talc near Tumkhera Khurd (21° 24′ : 80°13′) in the Bhandara district. Between 1908 and 1924 this area produced 84 tons of asbestos but no output is recorded since 1925. The mineral is known to occur in the hills near Saugor and Sanoda near Ludhora railway Station. The chrysotile variety has been noted as thin veins in the limestone near Bachai (22° 52′ : 79° 19′) and there is a possibility of finding workable veins in the neighbourhood (H. Crookshank. *Memoirs, Geological Survey of India,* LXVI, Part 2, p. 364, 1936).

Barytes (Barite).

One of the copper lodes at Sleemanabad in the Jubbulpore district proved to be rich in barytes, and a wagon load of this was despatched to Calcutta about the year 1904 for use in the works of the Shalimar Paint, Colour and Varnish Co., Ltd. The quality was, however, found to be poor. This locality is, in any case, not likely to be of much value as a source of barytes unless it should prove feasible to work the lodes for their metalliferous contents, and the barytes recovered as a by-product.

T. W. H. Hughes (*Mem. Geol. Surv. Ind.*, XIII, p. 47, 1877) has recorded the occurrence of a band of barytes, two inches thick, in a coal seam at Wun in the Yeotmal district.

Building materials.

Materials suitable for building purposes occur in great variety and abundance throughout the province and in all the geological formations. The alluvial tracts, not only of the Narbada, Purna, Wainganga, Kanhan and other big rivers, but also of many of the smaller streams, yield excellent brick-clays, whilst kankar is frequently abundant in the tracts of older alluvium. Laterite, as is well known, forms an excellent material for roads and culverts, and is abundant in some parts of the province, and its valuable variety, bauxite, has at times been unwittingly used for road-metal and building purposes (*e.g.*, in Balaghat). The Deccan trap areas provide an excellent building stone, *viz.*, basalt (*e.g.*, at Sitabaldi, on the Satpura branch of the Bengal-Nagpur Railway, and in many parts of Berar). It is also one of the best stones for macadam

roads and for concrete-aggregate. The so-called Lameta or Infra-trappean limestone, cropping out from below the Deccan trap in many parts of the province, *e.g.*, in the Satpuras and in Nagpur and Chanda (Karamgaon), constitutes an excellent ragstone, and has been successfully used for bridges on the Nagpur-Chhindwara branch of the Bengal-Nagpur Railway.

Turning next to the Gondwana formation, clay suitable for pottery purposes is quarried at Jubbulpore from the Jubbulpore group of the Upper Gondwanas. The same formation yields good fire-clay and pipe-clay. Other clay bearing divisions of the Gondwanas give excellent brick clays. Sandstones suitable for ashlar work and fine carving may be obtained from the Kamthi division of the Lower Gondwanas, well-known localities being Bhutara hill and Isapur in the Chanda district, Silewada near Kamptee, Akhund in Nimar and Ellichpur in Amraoti. Fine white sandstones are quarried at Sirgora and Pathe in Betul from the Talchir stage. The Pachmarhi sandstone is also a good building stone.

The Vindhyan formation is a well-known source of good building stones, the red, yellow and buff sandstones used in so many of the famous buildings of Northern India being derived from various divisions of the Upper Vindhyans. In the Central Provinces the Rewah group near Hoshangabad has yielded thin red sandstone flags for use as roofing tiles.

The Lower Vindhyan limestone of Katni has been quarried for some years by Messrs. Cook & Sons and others for lime-burning and building purposes, and is also now utilised by the Katni Cement and Industrial Co., Ltd., The Central Provinces Portland Cement Co. and their successors the Associated Cement Co., together with Lower Vindhyan shales, for the manufacture of cement. In recent years the cement production from near Katni has been between 150,000 and 200,000 tons annually.

The Raipur limestones and underlying Chandarpur sandstones of the Chhattisgarh basin are variously regarded as of Lower Vindhyan and Cuddapah age, more probably the latter. The limestones are now being extensively used for building purposes; in particular, a dark bluish limestone from Sikosa in the Drug district has been used extensively for flooring in buildings at Nagpur. The Pem or Penganga limestones (Cuddapah) are said to yield good building stone in places in the Chanda district (at Kandara). Future investigation may prove the suitability of Chhattisgarh for the

establishment of a cement industry based on the use of the Raipur limestone, with shale derived from one of the neighbouring coal-fields.

The building stones obtainable from the Bijawar formation are of inferior quality. The limestone has been used in the construction of temples at Khudia in Hoshangabad, but, owing to siliceous bands, is usually too hard to be worked with ease. The coarse sandstone of Chirakhan in the same district has been used for building the fort at Joga and temples in the neighbourhood. The red jaspers occurring in this formation might be used for ornamental purposes.

In the Archæan formations several excellent building an ornamental stones occur. The most valuable and beautiful is marble, often dolomitic, of Dharwarian age. The best known locality is the Marble Rocks in the Jubbulpore district, but numerous excellent marbles occur in the Betul, Chhindwara, Nagpur and Seoni districts. White marble is found in Betul and a pink marble in Narsinghpur. The most accessible localities are at Khorari in the Nagpur district, and in the Sausar tahsil of the Chhindwara district, where some beautifully marked serpentine marbles are found (*e.g.*, near Devi); but hitherto they have been used only for local railway culverts and bridges. In the Dharwar outcrops there are also bedded quartzites. *e.g.*, in the Ambagarh range in the Bhandara district. Such quartzites have been used in the forts at Ramtek and Ambagarh. A very pure quartzite, suitable for crushing for glass sand, occurs in large masses near Kishanpur, ten miles from Narsinghpur railway station. Amongst the various phyllitic and schistose rocks of the Chilpi Ghat series, slabby rocks suitable for roofing and flooring could perhaps be discovered. In the Archæan tracts of the Central Provinces there are also wide stretches of gneiss and granite, many of which would form excellent polished ornamental stone, *e.g.*, the gneissose granite near Jubbulpore and in the Satpuras near Lamta on the Jubbulpore-Gondia branch of the Bengal-Nagpur Railway, and some of the porphyritic rocks in parts of the Drug district.

Ceramic clays.

White clays are often seen in the Jabalpur beds of Jubbulpore and Chhindwara districts. The Jubbulpore potteries obtain their supplies from near the town. In Chhindwara district the clay beds are 2 to 3 ft. thick and sometimes as much as 10 ft. as for instance

near Muria (22° 45′ : 79° 7′). White clay is also seen east of Hithapathar (20° 40′ : 80° 53′) in Drug district. It is free from grit, plastic and resistant to heat up to near 1400°C. The product of weathering of the felsitic rocks in the same district is also a good plastic clay which however gives a greenish vitreous product on heating to 1400°C. The best occurrence of this type of material is between Jungera Malan and Bhandaritola in the Sanjari tahsil.

Coal.

The coalfields of the Central Provinces fall into three groups—the Chhattisgarh, Satpura, and Wardha valley. The Chhattisgarh field is continuous with that of the Son valley of Rewah State and the neighbouring areas. Some Upper Gondwana rocks conceal the coal-bearing Lower Gondwana (Barakar) rocks in this vast field.

The coalfields of this province were surveyed during the latter half of the last century and several reports have been published on them. For a general account dealing with the most important features of these fields, Vol. LIX of the *Memoirs, Geological Survey of India*, by Dr. C. S. Fox (pages 196-315) should be consulted.

The individual coalfields in the three main areas have been listed as follows by Dr. Fox, the figures in parenthesis being estimates of the reserves of coal in million tons :—

CHHATTISGARH COALFIELDS.

Northern (Sirguja) tract.

Sirguja	Tatapani-Ramkola.
Jhilmili	Jhilmili (3·5 million tons).
Korea	Sanhat.
Do.	Jhagrakhand (34).
Do.	Kurasia (40).
Do.	Koreagarh.
Sirguja	Bisrampur (Sirguja) (Large)
Do.	Bansar.
Do.	Lakhanpur (Large).
Do.	Panchbhaini.
Bilaspur	Damhamunda.
Do.	Sendurgarh (40).

Southern (Mahanadi) Tract.

Bilaspur	Hasdo-Arand or Rampur.
Do.	Korba (250).
Udaipur State	Mand River.
Do.	Kankani.
Raigarh State	Raigarh-Himgir.

SATPURA COALFIELDS.

Satpura area :	
Narsinghpur	Mohpani (4).
Betul	Betul (Shahpur).
	Sonada.
	Suki River or Gurgunda.
	Machna or Mardanpur.
	Golai or Katasur.
	Dulhara.
	Patakhera (15).
	Bamhanwara or Khapa.
	Upper Tawa valley.
Chhindwara :	
Kanhan valley area :	
	Damua-Kalichhapar.
	Ghorawari-Kolhia.
	Panara-Jinnaur.
	Datla-Jamai.
	Hingladevi or Ghogri.
Pench valley area :	
	Gajandoh.
	Barkuhi-Bhandaria-Bhutaria.
	Chandameta-Dongarchikli (15).
	Eklaira-Newtonchikli.
	Parasia-Khirsadoh.
	Rawanwara-Harrai.
	Dighawani-Chhinda.
	Sirgora-Haranbhatta.

WARDHA VALLEY COALFIELDS.

Chanda	Bandar (Chanda) (100).
Do.	Warora (Chanda) (12).
Yeotmal	Rajur or Wun (Berar) (240).
Chanda	Ghughur-Telwasa (Chanda) (1,500).
Do.	Chanda Town area.
Do.	Ballarpur (40--2,000).
Do.	Wamanpalli (1,500).
Do.	Kota-Chikiala.
Do.	Sironcha.

The coal in all the above coalfields belongs to the Barakar division of the Lower Gondwana System, but, in addition, coal has been found in the Upper Gondwanas, mainly in the Jabalpur division as for instance at Lameta Ghat, Sihora tahsil of Jubbulpore, Moran River area near Lokartalai, etc. The Upper Gondwana coal has,

however, never been considered worthy of exploitation except for local purposes, and is not referred to further.

Considering now the Lower Gondwana (Barakar series) coals of the Central Provinces, they are generally of a quality inferior to those worked in the Bihar coalfields. They fall in the second grade and third grade qualities of the Coal Grading Board classification, though a limited amount of first grade coal is found in some fields. The coal worked in the Pench valley fields which are the best producers in the Province, is of average second grade and is now finding a good market in the Central Provinces, Gujerat and Bombay.

As regards the quantities present only very rough estimates are available. A good deal of detailed work, both surface survey and underground exploration by numerous boreholes wherever the prospects are encouraging, will have to be done in order to bring our knowledge to the same level of accuracy and detail as is available for the important fields of Bihar.

The total coal available in the Province, including the States and adjoining areas, has been computed by Dr. Fox as: –

	Million tons.
Chhattisgarh-Mahanadi area	4,000
Satpura (Mohpani, Kanhan and Pench valleys)	1,000
Wardha valley	12,000
TOTAL	17,000

Of this total, the reserves of workable coal, *i.e.*, coal found in seams of 4 ft. thickness and over, and containing not more than 20 per cent. of ash, and occurring down to a depth of 1,000 ft. from the surface, will probably amount to:—

	Million tons.
Chhattisgarh-Mahanadi	1,000
Satpura region	150
Wardha valley	4,000
TOTAL	5,150

A part of this reserve however lies in Indian States, especially Raigarh, Korea, and Sirguja.

The output of coal from the coalfields of the Central Provinces and the quality of the material from the various occurrences can be gathered from the following tables.

Output of coal from the coalfields of the Central Provinces.

—	Average 1924-28.	Average 1929-33.	1934.	1935.	1936.	1937.	1938.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Ballarpur	151,092	222,166	321,038	312,591	247,122	264,269	279,353
Hoshangabad . . .	(1924) 3	..	..	..	..	..	..
Mohpani	(a) 72,682	..	..	..	..	..	..
Panch Valley . . .	487,753	796,134	1,117,942	1,214,099	1,259,133	1,234,233	1,369,208
Shahpur	(b) 665	..	..	..	1,727	5,657	5,288
Yeotmal	(a) 2,355	..	..	..	..	..	4,777
Korea State . . .	..	(b) 102,496	400,350	589,806	580,143	850,701	1,012,858
Raigarh State . . .	..	(1933) 2,131	3,162	2,181	2,625	2,500	2,600

(a) Average of three years.
(b) Average of four years.

K

Analyses of Coals of the

(The page number given in the last column is that in Memoirs, Geological Survey
note by Sir L. L. Fermor;

No.	Moisture.	Vol. matter.	Fixed carbon.	Ash.	Calories.
1	5·16	27·70	43·30	23·84	5617
2	13·83	28·04	47·59	10·54	6098
3	2·97	26·02	62·72	8·29	7092
4	5·79	28·22	44·80	21·19	—
5	4·19	24·00	44·00	27·81	—
6	7·20	31·06	55·05	6·69	7056
7	8·66	30·92	48·86	11·56	—
8	7·70	29·10	51·20	12·00	7000
9	6·32	29·35	58·06	12·59	6973
10	4·1	38·2	57·7	4·1	—
11	8·88	28·71	49·85	12·56	—
12	6·9	29·06	53·93	10·10	—
13	5·90	26·4	63·4	11·2	6449
14	8·40	27·0	39·44	25·5	5060
15	8·67	31·19	52·1	8·0	6222
16	4·10	24·46	25·49	44·95	—
17	4·77	25·53	34·20	35·50	—
18	2·52	24·26	48·71	24·01	6500 ?
19	2·84	20·55	37·42	38·24	—
20	2·44	30·76	49·58	17·24	6515
21	2·40	28·66	50·14	18·80	6348
22	3·76	29·80	39·96	26·48	5226
23	6·10	28·22	41·84	23·84	5372
24	7·86	29·64	44·41	18·09	Around 5700
25	2·26	29·00	50·34	18·46	Around 6000
26	7·38	29·98	44·52	18·12	5649
27	1·68	21·98	51·62	24·72	6224
28	7·48	31·24	44·24	17·04	5688
29	6·98	28·47	45·14	19·41	5668
30	7·69	29·99	42·12	20·20	5468
31	5·55	29·84	49·35	15·26	6286
32	?	28·0	61·6	10·4	—
33	8·1	25·4	38·6	27·8	5300
34	10·91	35·30	49·30	15·40	6539
35	13·0	30·3	53·7	15·7	6475
36	9·64	35·35	50·50	14·15	6371

Central Provinces.

of India, LIX ; F denotes that the analysis is taken from the previous edition of this S=Percentage of sulphur.)

Field and location.	Page.
Tatapani.—Tatapani *nala*, 2 miles N. W. of Bhormi	198
Ramkola.—Suknai *nala*, near Sarsera	199
Jhilmili.—Rangama *jharia*, E. N. E. of Kundhour, near Kupi	201
Sanhat.—Lower seam. Murwa and neighbourhood (average of 3 samples)	203
Sanhat.—Upper seam. Nagar area (average of 5 samples)	203
Jhagrakhand.—Bhukbhuka *nala*, 2½ m. S. W. of Khongapani	206
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Kurasia.—Chirmiri (average of 10 samples)	F
Kurasia.—Average of 3 seams now worked	211
Bisrampur.—Rer River	216
Lakhanpur.—(Laingha area) Lachi *nala* near Salih (average of 2, one from each seam)	220
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Korba.—Ghordewa seam. (Wagon of coal sent to Bombay)	235
Korba.—Sonpuri seams (average of 3 seams)	234 (S = 0·55)
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Kanhan valley.—(Damua)	267
Kanhan valley.—(Ghorawari)	268
Kanhan valley.—(Jinnaur).	270
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Pench valley.—Central part of the field (average of 7 samples)	..
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Pench valley.—(Barkui) full seam	280
Pench valley.—(Barkui) roof and floor coal	280
Pench valley.—(Chanda Meta)	282
Pench valley.—(Eklaira)	284
Pench valley.—(Newton Chikhli)	284
Pench valley.—(Rawanwara)	288
Pench valley. (Sirgora)	F
Warora	302
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Ghugus (average of 3 samples)	309
Ballarpur	312

In spite, however, of the existence of this large number of coal-fields, the majority have not been worked, partly owing to their situation as regards communications and partly on account of the rather inferior quality of the coal present. In the Wardha valley, the Mayo Colliery at Gughus was opened in 1870 but was soon closed down. The Warora colliery, which is 20 miles nearer the Bombay-Nagpur main railway line, was opened in 1873, and after being worked for 33 years was closed down in 1906 owing to subsidence and fire. The output of this colliery increased from 54 tons in 1874 to 153,336 tons in 1902. Interest was again taken in the Ghugus area and after some exploration after the War, a new colliery was established one mile south of the old Mayo pit, and subsequently another at Rajur. In 1900 coal was proved in the Ballarpur area and shafts were sunk in 1903 and 1906 through the enterprise of a firm in which Sir M. B. Dadabhoy is interested. Collieries are also working at Sasti, and in the neighbourhood of Chanda town at Mahakali, Babupet and Lalpet.

The occurrence of coal near Mohpani was long known and the first attempt to work it was about 1838, when 206 bullock loads were despatched for trial in the Bombay dock-yards. The Nerbudda Coal and Iron Co., Ltd., was formed in 1860 and a colliery opened at Mohpani in 1862, but railway connection was not made until 1870. The Sitarewara area of Mohpani experienced many difficulties which led to its abandonment and to the starting of work at Gotitoria (2 miles W. of Mohpani) about 1902. In 1904 the G. I. P. Ry. Co. acquired the properties of the Nerbudda Coal and Iron Co. and continued to work for about 22 years. In view of the difficulties of mining in this area and the much brighter prospects in the Bokaro field in Bihar, the G. I. P. Ry. decided to close down operations in 1927, the last recorded output of the Mohpani field being 71,482 tons in 1926. The field has produced about one million tons of coal when it was worked and about seven million tons of recoverable coal is estimated to be still present there.*

The Pench Valley area has received a considerable amount of attention from about 1852, when coal is said to have been discovered there. Coal has been worked here in a small way since 1866, when a mine was opened at Barkuhi. In 1905 the B. N. Ry. extended their narrow gauge line from Chhindwara to Barkuhi and it was in

* *Mem. Geol. Surv. Ind.*, LIX, p. 254-255, (1934).

this year that mining on a decent scale was established at Chandameta in this area. Nagpur and Chhindwara were connected by rail (B. N. Ry.) in 1912, and the Amla-Parasia (G. I. P. Ry.) extension was opened in 1915. The output in 1905 was 1,104 tons; it passed the 100,000 mark in 1915, and is at present about 1¼ million tons per annum. The most important firm working in this field is Messrs. Shaw, Wallace & Co. of Calcutta.

Copper-ore.

Copper-ores have been discovered at several localities, but none of these occurrences has hitherto proved to be large enough for exploitation by modern methods. The best known occurrence is at Sleemanabad in the Jubbulpore district, where a series of veins up to 4 feet wide, and cutting across the strike of dolomites of Dharwarian age, was made the object of prolonged prospecting operations by Messrs. P. C. Dutt and Burn & Co. some years ago. The chief ores found were chalcopyrite, tetrahedrite, and galena, with barytes, and selected samples yielded up to 200 ounces of silver per ton. The lodes did not, however, prove to be large enough nor sufficiently persistent to justify mining operations. Azurite and malachite, with oxides of copper, occur disseminated through schists regarded as of Bijawar, but more probably of Dharwar, age, at Birman Ghat on an island in the Narbada in Narsinghpur district. These ores were mined by the Nerbudda Coal and Iron Co. some 45 years ago, and a certain quantity of the ore was sent to England, but the mine was ultimately abandoned. Several of the early samples yielded from 12·6 to 47·8 per cent. of copper, the average yield being 28 per cent. Encrustations of copper carbonates have been found in excavations on a quartz reef in the Chilpi Ghat series at Malanjkhandi in the Balaghat district, and also in the galena-quartz vein traversing the gneiss near Chicholi in the Drug district (see page 401).

Fire-clay.

Fire-clay is often found in the Indian coal measures, associated with coal-seams, frequently as an under-clay, and could probably be obtained from most of the coalfields of the Central Provinces if required. In particular, it has been noticed as a stratum 11′ 3″ thick above No. 2 seam at the Warora colliery. Some of the white

Upper Gondwana clays of Jubbulpore are found to be exceedingly refractory and are used in Messrs. Burn & Co.'s and other local pottery works.

Fluor-spar.

Fluorite is found in small quantities in the galena-quartz vein at Chicholi in the Drug district; in minute quantities in a vein of altered quartz-porphyry carrying copper and lead-ores at Sleemanabad in the Jubbulpore district; also as a vein in carbonaceous shale adjoining a dolerite dyke near Rawanwara, Chhindwara district.

The most promising of these occurrences is the deposit at Chandi Dungri near Chicholi (about 14 miles from Dongargarh) on the border of Nandgaon and Khairagarh States. According to Dr. J. A. Dunn of the Geological Survey of India who visited the deposit in the cold weather of 1938-39, it occupies a shear-zone in granite and consists mainly of quartz with varying amounts of fluor-spar and some felspar. The vein is about 30 ft. wide across the Great Eastern Road near Chicholi and extends for some 400 ft. north of the road (in Khairagarh) and 500 ft. south of the road (in Nandgaon). The richest portion is the centre of the vein, the fluorite content varying from anything up to 85 per cent. of the vein stuff, with an average of perhaps 50 to 60 per cent. A good deal of the material can easily be concentrated to a marketable grade (around 85 per cent.) by hand picking. The Tata Iron and Steel Co. have recently prospected the deposit in detail and are said to have applied for a mining lease.

Fuller's Earth.

This substance has been raised for some years from the Lower Vindhyan rocks at Katni. The annual output was over 350 tons during 1922 to 1926, but has diminished to around 40 tons during the last few years.

Gemstones.

Diamonds were formerly worked at Wairagarh in the Chanda district, but by 1843 the workings had been abandoned. The gems are said to have been obtained from a lateritic grit, and it is suggested that the source of the diamonds was the Lower Vindhyan (? Cuddapah) rocks of this district. The geodes of the Deccan trap formation are the source of many varieties of semi-precious stones,

all of them forms of silica, such as agate, carnelian, onyx, jasper, amethyst and rock crystal. These minerals are commonly found in rivers draining off the Deccan trap, and their abundance in the bed of the Narbada has led to the establishment of an Indian lapidary industry at Jubbulpore, where many varieties of polished agate may be purchased. Although it is not a gemstone, yet it is convenient to mention here that crystal-clear pieces of calcite suitable for use as Iceland spar for optical purposes are sometimes found in geodes in the Deccan Trap. Such material would probably prove to have a considerable market value.

The Archæan rocks occasionally contain rose-quartz suitable for use as an ornamental stone, as at Khairi in the Chhindwara district. The crystalline limestones of this district sometimes carry a lilac-coloured spinel, which has not hitherto been found in gem quality, however.

Gold.

Alluvial gold has been obtained from time immemorial by local gold-washers or *jhoras* from the river-sands and gravels of the province, but there is no evidence that it exists anywhere in sufficient quantity to be worth exploitation by modern methods. Amongst the districts and states that have thus yielded alluvial gold are Balaghat, Bastar, Bhandara, Bilaspur, Jashpur, Mandla, Raipur, Seoni and Udaipur. Such alluvial gold has probably been derived ultimately from the ancient Archæan rocks, but the only localities where gold has been obtained *in situ* are Sonakhan in the Bilaspur district, where a gold mine is said formerly to have existed, and Sleemanabad in the Jubbulpore district, where gold has been found in the copper-ores in quantities ranging up to 15 dwt. per ton. Small quantities are won from alluvial washings now-a-days, but the amount probably does not exceed 200 ozs. per annum.

In the Dharwarian rocks in the area south-east of Sleemanabad, Jubbulpore district, there occur several bands of crushed conglomerates varying in thickness from a few feet to 100 feet, and containing chalcedony, quartz, sericite, chlorite and ferruginous matter in the matrix. These were prospected in detail a few years ago by a private firm but the gold values were poor, ranging between 0·2 to 0·8 cwt. of gold per ton. A few veins of bluish quartz in the area, however, gave better values, up to 4 cwts. per ton, but the

veins are thin, sparsely distributed and quantitatively unimportant. (*Rec. Geol. Surv. Ind.*, LXVII, pp. 32-33, 1933.)

Graphite.

A deposit of graphite occurs three miles north of Betul in a zone of carbonaceous phyllite, the western end of which has been recrystallised to graphitic phyllite. The dip of the phyllites is very steep to vertical and some folding is also seen. They contain bands up to 10 feet wide in which the graphite content rises to 18 to 30 per cent. of the rock. The material is quarried, crushed and concentrated by washing which raises the graphite content to 35 per cent. The desposits have only recently been opened up and are thought to be extensive. They are now worked by Messrs. Dhanjee Devjee & Sons who sell the concentrate to metal foundries.

Iron-ore.

Iron-ores are widely distributed throughout the province, which is now perhaps the chief home in India of iron-smelting in small indigenous blast furnaces. The following table shows the number of furnaces at work during recent years:

—	1909.	1913.	1918.	1923.	1926.	1928.	1933.	1937.	1938.
Bilaspur . .	103	99	131	100	102	102	52	50	59
Balaghat .	4	..	..	..	..	..	..	..	..
Chanda . .	9	20	..	..	..	..	..	4	..
Drug . .	56	40	101	19	..	16	5	6	6
Jubbulpore .	26	29	..	..	1	1	..	..	..
Mandla . .	65	49	..	..	36	54	54	38	21
Narsinghpur .	4	..	..	..	..	..	..	..	..
Raipur . .	230	181	..	..	68	20	2	8	50
Saugor . .	13	19	..	..	4	3	1	..	..
TOTAL .	510	437	232	119	211	196	114	110	136

Returns showing the quantity of iron produced in these furnaces are no longer available, but the average annual yield per furnace is only about 1½ tons. At one locality, Ghogra, in the Jubbulpore

district, manganiferous iron-ore is smelted with the production of a steely iron known as *kheri*.

The iron-ores are found in four geological formations, *viz.*, laterite, the Chikiala and Barakar divisions of the Gondwana, the Bijawar, and the Dharwar, of which the last is the most important to the modern smelter.

Lateritic ores are most abundant near Katni in the Jubbulpore district, but are also found in Drug, Saugor, Yeotmal and other districts. In the Jubbulpore district the lateritic ores are well seen at Bijori and in the Kanhwara hills; in the latter locality three bands of ore, ranging from 2 to 2½ feet thick, are estimated to contain 49 million tons of ore. One sample yielded 57·52 per cent. of iron and 0·76 per cent. of P_2O_5.

Further south in this district, the upturned edges of the Dharwar hematites are capped by lateritoid limonitic ores formed by replacement.

Brown and red hematite occur abundantly as bands and nodules in the sandstones of the Chikiala stage in the valley of the Pranhita, and are smelted in indigeous furnaces at Yemlapali in Hyderabad territory and at neighbouring localities in the Chanda district.

The ores of Barakar age occur as iron stone zones at two horizons in the Raigarh-Hingir coalfield in Raigarh State, being most abundant near Kodoloi.

Iron-ores are also found in the Bijawar rocks in Nimar, Hoshangabad and Narsinghpur. In the two former districts the ores are almost invariably hematite, obtained from breccias occurring in the Bijawar series near the junction with the Vindhyans, or from debris derived from the same rocks. There is no evidence that these ores exist in sufficient quantity to interest a modern smelter, although they have been largely used in the past by the local smelter.

Narsinghpur district.

At Omarpani near Tendukhera in the Narsinghpur district both hematite and limonite occur irregularly distributed in fissures and hollows among the Bijawar limestones and quartzites, and were formerly smelted extensively by indigenous methods. In 1855 to 1857 some 70 to 80 furnaces were at work with a production of about 140 tons of iron annually. This metal was of unusually good quality, and a portion of it was converted into steel by re-heating, hammering, rolling in burnt cow-dung, and plunging into water. No estimate of the quantity of ore available appears to have been made.

The most valuable and abundant of the Central Provinces iron-ores occur in the Dharwarian rocks, particularly in the Chanda, Drug and Jubbulpore districts, and also in Bastar State. Magnetite has been reported from the Archæan tracts of Kenda zamindari, Bilaspur district.

Chanda district.

With the exception of the Chikiala ores referred to, the iron-ore deposits of the Chanda district are all situated in the Archæan tracts, where they form well-marked beds usually associated with Dharwarian rocks. The ore is usually hematite associated with banded hematite-quartzites, but magnetite is sometimes present. At least ten separate deposits have been located, and although they have not yet been exhaustively prospected, there is little doubt tht some of them are of large size. The two best known are Lohara, where the iron-ore forms a hill 650 yards long, 200 yards wide and 120 feet high, and has been traced for a further distance of 2½ miles; and Pipalgaon, where a very large mass of red hematite has been located.

In 1875 unsuccessful experiments were made at Warora in smelting iron-ore from Lohara and Ratnapur with Warora coal and a few years later a scheme was proposed for the establishment of modern iron works at Durgapur on the Erai river to smelt the ores of Lohara and Pipalgaon with charcoal fuel, the suggested scale of production being 25,000 tons of pig iron annually. Nothing, however, resulted from this proposal, and the Lohara deposit is now leased to the Tata Iron & Steel Co., Ltd., and held in reserve, except when small quantities of this very low-phosphorous ore are required for special purposes at Jamshedpur. The quality of the Chanda ores can be judged from the following analyses :—

——	Fe.	SiO_2.	S.	P.
Asola	65·99	3·89	..	..
Dewalgaon	61·2	11·04	..	..
Do.	67·76	1·50	..	..
Lohara	69·21	0·82	0·012	0·005
Pipalgaon	71·05	4·5	Trace	Trace
Poser	69·8	..	..	..
Ratnapur (limonite)	49·7	26·0 (Insol.)	..	..

The occurrence of valuable iron-ores in parts of the Raipur district (now included in Drug) was not known until Mr. P. N. Bose briefly referred to the chief deposits in a paper published in the *Records, Geological Survey of India*, Vol. XX, page 167 (1887). The district having been explored again on behalf of Messrs. Tata Sons & Co., by Mr. C. M. Weld, a large area in the Dondi-Lohara zamindari in the western part of the district was taken up under prospecting license for detailed examination. The iron-ores, on account of their resistance to weathering agents, stand up as conspicuous hillocks in the general peneplain. The most striking of these is the ridge which includes the Dhalli and Rajhara hills, extending for some 20 miles in a zigzag, almost continuous line, and rising to heights of sometimes 400 feet above the general level of the flat country around. The iron-ores are associated with phyllites and are often of the usual type of banded quartz-iron-ore schists characteristic of the Dharwar system. But in places, thick masses, apparently lenticular in shape, are formed of comparatively pure hematite, and one of these in the Rajhara hills has been subjected to very careful examination by diamond drilling. The Rajhara mass was carefully sampled across the surface at each point selected for a drill hole, and the cores obtained were also analysed in lengths representing successive depths of 10 feet each from the surface, giving altogether 64 samples, which were assayed for iron, phosphorus, sulphur, silica and manganese. The average results obtained for the surface samples were as follows: Fe, 66·35; P, 0·058; S, 0·108; SiO_2, 1·44; Mn, 0·151 per cent.; while for the cores the averages were Fe, 68·56; P, 0·064; S, 0·071; SiO_2, 0·71; Mn, 0·175 per cent.

Drug district.

In this mass the prospecting operations thus proved the existence of 2½ million tons of ore carrying about 67·5 per cent. of iron and a phosphorus content slightly below the Bessemer limit. The quantity estimated is that which may be regarded as ore in sight, while almost certainly much larger quantities may be obtained by continuation of the ore-bodies beyond their proved depth.

During the recent geological mapping of this district, Mr. B. C. Gupta of the Geological Survey of India estimated the reserves of

ore in the Dondi-Lohara zamindari as follows (*Rec. Geol. Surv. Ind.*, 72, p. 52, 1937):—

Location.	Reserves million tons.	Per cent. iron.	REMARKS.
Rajhara pahar . . .	7·5	68—69	Prospected by Tatas. Ore proved to 150 ft. depth.
W. of Rajhara pahar (20° 34′: 81° 6′).	37·5	67	Thickness of 150 ft. assumed.
Peak 1990, S. of Jharandalli (20° 34′: 81° 4′).	24	69	Ditto.
Kondekasa (20° 35′: 81° 4′) .	25	68	Ditto.
Ridge 2156 S. of Kondekasa .	20	66	Ditto.

Jubbulpore district.

The iron-ores of the Jubbulpore district have long been famous, and, although the native industry now exists on only a small scale, some of the localities such as Majhgaon near Sihora, are very accessible, so that the indigenous processes of iron smelting can be readily studied. A fine red ochre has been quarried for some years for paint manufacture at Jauli. The lateritic limonite deposits of this district have already been referred to. The hematite deposits, apparently interbedded with the Dharwar phyllites, had for years been supposed to be very rich, but prospecting operations conducted in this area by E. P. Martin and H. Louis have shown that while iron-ore is widely distributed, and the formations in which it occurs are prominent in the district, there are no rich ore-bodies of large size that could be relied on for the output necessary to maintain an important industry; and most of the ore, being in the form of soft micaceous hematite, would be physically unfit in its natural condition for use in a blast furnace. Generally, also, the ores in this district contain a proportion of phosphorus too high for acid Bessemer steel.

The following analyses, extracted from Messrs. Martin and Louis' report (*Agricultural Ledger*, Calcutta, 1904, No. 3), give an idea of

the nature of the ore in the principal occurrences in the Jubbulpore district :-

—	Iron.	SiO^2.	S.	P.	Moisture.
I. Agaria hill lateritic cap covering most of the hill. 3 samples.	57·58 56·85 45·67	7·28 8·17 13·90	0·02 0·02 0·03	0·125 0·125 0·187	0·45 0·67 0·69
Soft micaceous hematitic schists. Ore-layers only. 2 samples.	60·70 58·40	7·45 8·40	0·019 0·022	0·075 0·081	0·25 0·33
II. Agaria ridge. Bed of hematite 4 to 5 feet thick, dipping 50°.	50·07	11·37	0·036	0·074	0·44
III. Jauli. Soft banded hematite-quartz-schists. Picked samples.	64·67 54·64 65·50 55·22	3·70 16·05 3·37 17·32	0·027 0·033 0·032 0·030	0·023 0·200 0·110 0·053	0·30 0·48 0·33 0·21

The hematitic ores occur interbedded with Dharwar phyllites. Near Sihora siliceous brown hematites were found, poorer in iron, but physically more suitable for the blast furnace, and in this area there occur patches of manganiferous iron-ore.[1] The following analyses were obtained from samples obtained at Mansakra (Silondi) near Sihora :—

	Fe.	Mn.	SiO_2.	S.	P.	Moisture.
Wider band . .	52·15	0·36	14·70	0·022	0·385	0·10
Narrower band .	44·95	6·28	14·55	0·027	0·352	0·27
Manganiferous iron-ore	24·45	21·17	19·60	0·022	0·163	0·80

The above ores occur as lateritoid replacement products on the upturned edges of the Dharwar hematite ores.

Though the occurrence of high grade iron-ore in Bastar State has been known for many years, no details were available, since all the work hitherto done was by commercial firms. Dr. H. Crookshank and Dr. P. K. Ghosh have just completed the geological mapping of a part of Bastar and the former has given a short account of the iron-ores in the Transactions of the Mining, Geological and Metallurgical Institute of India volume 34, pp. 253-281 (1938) in a paper entitled 'Iron ores of the Bailadila Range, Bastar'.

[1] *Cf. Rec. Geol. Surv. Ind.*, XVI, pp. 101-103, (1883); *Trans. Min. Geol. Inst. Ind.*, 1, p. 99, (1906) and *Mem., Geol. Surv. Ind.*, XXXVII, pp. 814, 815, 821-823, (1909).

The iron-ores occur in the 'Bailadila iron-ore series' which resemble the 'Iron-ore series' of Singhbhum and the adjoining Orissa States. They consist of banded hæmatite-quartzites, ferruginous schists, phyllites and conglomerates presumably of late Pre-Cambrian age. The iron-ores occur generally at the contact of the banded hæmatite-quartzites and the ferruginous schists and are thought to be due to the replacement of the former by iron-ore. The deposits have been grouped into fourteen groups as shown below:

Location.	Reserves in million tons (over 65% Fe)
1. Cliffs 2½ miles E. by S. of Kondapal (18° 50′ : 81° 11′) .	33
2. Hill 3,700, W. N. W. of Porowada (18° 46′ : 81° 12′) .	10
3. 1 mile N. W. of Bailadila Guest House	26
4. Ridge S. of hill 3,850, 3 miles S. by W. of Bailadila Guest House	Smal
5. Hill 4,150, 2¼ miles north of Loa (18° 38′ : 81° 11′) .	155
6. 2 miles N. by E. of Guest House, near base of cliffs .	..
7. 1 mile N. by E. of Guest House, near the top of cliff .	..
8. 1 mile S. by E. of Guest House, near the top of cliff .	Large
9. 1½ miles S. by E. of Guest House, about 2,750 contour .	..
10. From hill 4,055 to hill 3,936, S. of Guest House . .	28
11. Along the high ridge 1½ miles E. of Taki (18° 38′: 81° 13′) between hills 4,065 and 3,978 (numerous deposits) .	..
12. 2½ miles N. E. to 2½ miles S. E. of Taki near 2,750 contour	Small
13. 2 miles S. W. of Taki	100
14. 2 miles S. S. E. of Taki	156
TOTAL .	508
Add 10 per cent. for the unestimated deposits .	51
Add 10 per cent. for float .	51
Grand total of estimated reserve .	610

This is stated to be a conservative estimate of the ore in sight, as some of the deposits are bound to continue to greater depths than those assumed in the calculations. There are, in addition, enormous masses of ferruginous conglomerates and lateritic hæmatite, much of which will be workable ore of high grade. The good hæmatite ore in the deposits enumerated above average 66 to 69 per cent. metallic iron, 0·06 to 0·12 phosphorus and 0·02 to 0·05 sulphur.

Lead and Silver.

Lead-ores have been located in several places in this province, but in no case have these occurrences been found to be of sufficient magnitude for exploitation by modern methods. As would be expected, the majority of these deposits are in Archæan rocks but strings and nests of galena have been found in Cuddapah limestone in the bed of the Mahanadi river near Padampur in the Bilaspur district, whilst some old excavations in the Bijawar limestone at Joga Khurd in the Hoshangabad district yielded a sample of limestone with disseminated galena carrying 21 ounces of silver to the ton of lead.

The other occurrences are in Archæan rocks. The most important deposit is probably that at Ranitalao near Chicholi in the Drug district, where a well-marked quartz-vein, ranging in width from 6 to 30 feet, has been traced for a distance of 1½ miles through gneiss. The vein contains both galena and fluor-spar, but the proportion of galena to vein-stuff appears to be small, probably less than 1 per cent. Specimens of ore yielded over 9 ounces of silver per ton of lead. Stringers of galena occur with quartz in a highly cleaved buff shale at Thelkadand in the Panabaras zamindari and at Karamtara in the Ambagarh zamindari, Drug district. A small output of lead-ore from this district was reported in the years 1914 to 1916, but it is not known whether the production was from Ranitalao mentioned above.

An outcrop, about 50 yds.×8 yds., of quartz vein with lead and copper ores occurs in a country of slates and greenstone, 600 yds. west of Muhripar (21° 21′ : 80° 52′). The ore occurs both in the quartz vein and the adjoining country rock as veins and stringers.

Argentiferous galena also occurs in association with the copper-lodes of Sleemanabad in the Jubbulpore district, whilst fragments of galena have been found near Nimbha in the Nagpur district. Finally ganela has been recorded from two localities (Bhelaunda and Chirai Khurd) in Sirguja State.

Lignite.

In 1884, Mr. P. N. Bose described an occurrence of lignite in logs up to 6 inches in diameter embedded in alluvial peaty clay below the sand of the Karun river 3 miles south-west of Raipur. Similar deposits were said to occur at other localities in the same

neighbourhood, and Mr. Bose concluded that the quantity available might be considerable. The composition was as follows (average of two samples) :—

	Per cent.
Moisture	16·70
Volatile matter	48·60
Fixed carbon	29·15
Ash	5·55
	100·00

Lithographic Stone.

The occurrence of stone suitable for lithographic purposes has been recorded from two localities in the province. The material from one source, *viz.*, the Raipur district, and therefore presumably a Cuddapah limestone, was formerly used at the Raipur Jail press. The other locality is near Hatta in the valley of the Sonar river in Damoh district, where a thin-bedded compact limestone of Upper Vindhyan age is found. No trial of this stone appears, however, to have been made.

Manganese-ore.

Judged either from quantity or value of the annual production, the manganese-ore industry is the most important mineral industry of the province, which contains some of the finest manganese-ore deposits in the world. These deposits are associated with a series of rocks known as the gondite series (forming a portion of the Sausar series*), regarded as metamorphosed manganiferous sediments of Dharwar age and characterised by the presence of various manganiferous silicates, the most important of which are the manganese garnet, spessartite, and the manganese-pyroxene, rhodonite. Ocassionally peroxide ore is found, *e.g.*, at Dungri Buzurg where ore analysing 84-88 per cent. peroxide has been produced in large quantities. Ore high in manganese-dioxide and very low in iron occurs also at Pali in the Nagpur district. The Sitapar mine (Chhindwara district), which produced 70,600 tons of very high grade ore between the commencement of work in 1906 and final closing down in 1921, was unique in containing ore composed of sitaparite, hollandite and fermorite at and near the surface, these minerals however giving place to braunite below a depth of 60 ft. The rocks of the gondite series are developed typically in the Chhindwara, Nagpur, Bhandara and Balaghat districts (and to a small

* *Rec. Geol. Surv. Ind.*, LIX, p. 78, (1926).

extent in Seoni). The ore-bodies consist typically of braunite and psilomelane, occasionally with hollandite, vredenburgite and sitaparite, and occur as lenticular masses and bands intercalated in quartzite, schists and gneisses of Archæan age. They are often well-bedded and in conformity with the associated rocks, the beds being sometimes persistent over long distances. For example, a manganiferous zone extends over a distance of 12 miles from Dumri Kalan to Khandala in the Nagpur district, and includes the deposits at Beldongri, Lohdongri, Kacharwahi and Waregaon. The band running through Jamrapani, Tirodi and Ponia in the Balaghat district is practically continuous for 6 miles. The ore-bodies may attain large dimensions. The Balaghat deposit is $1\frac{3}{4}$ miles long and the Manegaon deposit is $1\frac{1}{2}$ miles long. The large apparent thickness of many of the ore-bodies is generally due to repetition and coalescence by folding.

A second type of ore, which however does not usually form deposits large enough for profitable working, occurs as bands and nodules in crystalline limestone and contain the manganese-epidote piedmontite. This type is found in Nagpur and Chhindwara districts. In the portion of the Balaghat district east of the Wainganga river the manganese-ore horizon occurs near the base of the Chilpi Ghat series, which is regarded as a less metamorphosed facies of the rocks to the west of the Wainganga. That a portion at least of these ores is of primary origin is proved by the occurrence in intrusive pegmatites of fragments of the invaded manganese-ore deposit.

Although the occurrence of manganese-ore in this province has been recorded on several occasions from 1829 onwards, it was not until 1899 that the first prospecting license was applied for in the Nagpur district, the first shipment taking place in 1900. Work commenced in the Balaghat district in 1901, in the Bhandara district in 1903, and in the Chhindwara district in 1906, and together these four districts have been responsible for practically the whole of the output of manganese-ore from this province up to date. In the first year, 1900, the production totalled 47,257 tons, rising to 351,880 tons in 1906 and 565,017 tons in 1907; thereafter it has averaged about 500,000 tons annually, with a high record of 649,307 tons in 1913. This was eclipsed in 1926 when an output of 761,365 tons was recorded, the highest figure yet attained. In sympathy with the depression which set in, this was followed by a rapid decline

to barely 28,789 tons in 1933 when many mines closed down. Since then, however, the industry has gradually recovered, the output for 1936 and 1937 being 568,806 and 695,177 tons respectively. Except for small quantities of this ore that have been smelted at Jamshedpur and Kulti for the production of ferro-manganese, the whole of this ore is exported. The export values of the Central Provinces manganese-ore production since 1906 have fluctuated between £32,868 in 1933 and £3,054,137 in 1920, the highest prewar total being £1,314,412 in 1907.

As an index to the large size of some of these deposits, the following table may be of interest :—

Total production of manganese-ore from the mines in the Central Provinces, which have yielded over 100,000 tons of ore by the end of 1937.

Mine.	District.	Year of commencement of work.	Total production up to end of 1937.
			Tons.
Tirodi	Balaghat	1902	2,219,969
Balaghat	Do.	1901	1,813,481
Kandri	Nagpur	1900	1,333,687
Chikhla (with Edarbuchi)	Bhandara	1901	1,127,604
Mansar	Nagpur	1900	1,066,673
Kachhi Dhana	Chindwara	1906	920,700
Kurmura (with Ponwar Dongri, Dongri Buzurg, Balapur Hamesha).	Bhandara	1902	601,370
Sitasaongi	Do.	1908	574,611
Kodegaon	Nagpur	1903	535,611
Gumgaon	Do.	1901	523,167
Ramrama	Balaghat	1906	444,191
Miragpur	Do.	1905	347,485
Lohdongri	Nagpur	1900	340,663
Sukli	Balaghat	1905	327,136
Ukua (with Samnapur and Gudma)	Do.	1906	241,835
Ramdongri	Nagpur	1901	235,532
Netra	Balaghat	1908	170,495
Satak	Nagpur	1904	164,004
Jamrapani	Balaghat	1906	157,801
Shodan Hurki	Do.	1912	148,247
Sitapathar	Do.	1906	147,684
Junawani	Nagpur	1906	141,096
Manegaon (with Rowadbandhi and Hirapur).	Do.	1902	132,782
Kosumba	Balaghat	1905	131,400
Kacharwahi	Nagpur	1902	121,519
Mandri	Do.	1902	117,870
Ponia	Balaghat	1906	116,661

The quality of the manganese-ores from these four districts may be judged from the following figures:—

Range of analyses of manganese-ores from the gonditic deposits of the Central Provinces.

—	Balaghat.	Bhandara.	Chhindwara.	Nagpur.
Number of analyses.	13	13	9	30
Manganese . .	49·08-54·51	49·00-54·07	48·95-54·97	42·28-56·52
Iron . . .	5·28- 9·10	3·86-10·25	5·00-11·77	2·09-16·34
Silica . . .	1·62- 6·02	2·08- 6·50	4·98-10·63	2·90-18·48
Phosphorus . .	0·04- 0·24	0·06- 0·34	0·06- 0·28	0·04- 0·65
Moisture . .	0·12- 0·85	0·09- 1·00	0·00- 1·27	0·11- 1·32

Means of above analyses.

—	Balaghat.	Bhandara.	Chhindwara.	Nagpur.
Number of analyses.	13	13	8	30
Manganèse . .	51·88	51·94	52·72	51·53
Iron . . .	7·40	7·27	7·08	6·24
Silica . . .	3·74	4·59	7·16	7·25
Phosphorus . .	0·11	0·14	0·11	6·215
Moisture . .	0·37	0·44	0·38	0·49

The above samples were taken at or close to the surface, and deeper working is revealing a tendency towards a progressive increase of phosphorus contents with depth. A distinct tendency to lower grade has also been noticed during the last 15 years.

For information as to costs of working and other economic conditions, reference should be made to the section of 'Manganese' in *Records*, Vol. LVII (1925), Vol. LXIV (1930) and LXX (1935).

In addition to the gonditic areas referred to above, relatively unimportant manganese-ore deposits are found near Sihora and Gosalpur in the Jubbulpore district on the outcrops of rocks of Dharwar age, associated with the latter in such a manner as to leave little doubt that the ores have been formed by the replacement, at the surface, of Dharwar phyllites and quartzites. The masses of ore thus formed do not consist entirely of manganese-ore but often contain considerable quantities of iron-ore; and every gradation is to be

found from manganese-ores through ferruginous manganese-ores and manganiferous iron-ores, to iron-ores. The masses of ore thus formed are often more or less cavernous and bear considerable resemblance to ordinary laterite and have in consequence been called lateritoid ores. The mineral composition of the ores thus formed is usually fairly simple. The manganese-ores are pyrolusite, psilomelane, and wad, whilst the iron-ores are limonite and earthy hematite. Chemically, these lateritoid ores show a greater range of composition than the gonditic ores. The manganese is usually relatively low, so that the ores won consist mainly of second-grade manganese-ores and third-grade ferruginous manganese-ores. Such deposits, would be worked to the greatest advantage if a market could be found for the iron-ores and manganiferous iron-ores, as well as for the manganese-ores. The ores of this district are of little value economically, but there has been a small output in recent years, possibly for special purposes :—

1907	7,100
1908	48
1910	300
1915	11
1916	576
1917	300
1918	65
1919 to 1922	*Nil.*
1923	55
1924	1,850
1925	1,901
1926	100
1927	181

No production since 1927.

The quality of the ores available is shown by the following analyses :—

—	MANGANESE-ORE.		MANGANIFEROUS IRON-ORE.	
	Range.	Mean.	Range.	Mean.
Number of analyses.	3	3	7	7
Manganese	34·53-56·80	45·56	6·20-25·60	20·26
Iron	1·60-10·30	4·79	19·17-47·10	28·78
Silica	1·40- 4·79	2·68	4·40-23·40	12·99
Phosphorus	0·03- 0·46	0·215	0·02- 0·85	0·25
Moisture	0·39- 0·90	0·56	0·12- 0·65	..

Two occurrences of manganese-ore, at Ratanpur and Gorakona in the Bilaspur district, consist of pyrolusite, psilomelane and wad, formed by the replacement of rocks mapped as belonging to the Chilpī Ghat series.

In addition to the occurrences referred to above, manganese-ores of no economic significance have been found in several other districts. Impure wad has been found at Sontulai in the Hoshangabad district, associated with rocks of presumed Bijawar age. In the Chandgarh tract and Harsud tahsil of the Nimar district four occurrences are known associated with four different geological formations, *viz.*, Bijawar, Vindhyan, Lameta and Deccan trap, and, except the last, are probably examples of surface impregnation and replacements, and are of no economic value. In the Yeotmal district, manganiferous sandstone and nodules of manganese-ore in red clay, both of Lower Gondwana age but of no value, have been found.

Mica.

In the Central Provinces pegmatitic rocks abound, but although a certain amount of attention has been given to mica by prospectors, no deposits worth exploitation have yet been located. The largest plates hitherto discovered were obtained from Jungani in Bastar State and measured 4 to 5 inches across, but they were weathered and damaged by gliding planes. Attempts to work mica have also been made at Chitadongri and Bamni in the Balaghat district and at Komochoki in Bilaspur district. Flawed and small size mica also occurs in the pegmatites of Narsinghpur and Chhindwara, *e.g.*, at Bandra Kalan.

Lithia Mica (Lepidolite).

Two deposits of lepidolite have been found in the Bastar State. The first occurs about 400 yards south of Mundvel (18° 39′ : 81° 56′) and extends east to west for several hundred yards.

The second occurrence is 600 yards south by west of Mundvel on the face of a hill. It occurs in a pegmatite dyke which is 30 ft. wide and over 70 yards long, the central 15 feet of the width being rich in the mineral. It has been estimated (*Rec. G. S. I.*, 71, p. 45, 1936) that the proportion of quartz to lepidolite is about 6 to 1, and that for every foot of depth of this deposit 15 tons of lepidolite will be available. The total quantity available will run into several

hundred tons. An analysis of the mineral showed 3·34 per cent. lithium oxide and 4·88 per cent. fluorine.

Mineral Waters.

Although India is endowed with a large number of thermal and medicinal springs, yet no attempt has been made by modern enterprise to turn these resources to account. In the Central Provinces the following springs are known :—

District.	Locality.	Situation.	Temperature.	Properties.
Chhindwara . .	Anhoni . .	Trap dyke . .	134° F. .	Sulphurous.
Hoshangabad .	Anhoni Samoni .	Trap dyke . .	114° F. .	Sulphuretted hydrogen.
Sarguja . .	Tatapani (Taptapani).	Line of fracture .	136°-190° F.	Sulphuretted hydrogen and deposits siliceous sinter.
Yeotmal . .	Khaur . .	..	87° F. . .	Deposits calcareous tufa.

Ochre.

Both red and yellow ochres occur at several localities in the province, and for many years there has been a small industry for the manufacture of paint from the red ochre mined at Jauli in the Jubbulpore district. The occurrence is in rocks of Dharwar age.

Red ochre is also obtained in the Gandai and Thakurtola zamindaris in the Drug district and in the Salitekri hills in the Balaghat district—in all cases probably from the Chilpi Ghat series, the local form of the Dharwars.

Yellow ochres are said to be found in the Chanda district and near Kalmeshwar in the Nagpur district.

Small lenses of earthy hæmatite are found along the northern border of Jabalpur strata, especially between the Sukkur river and the Narsinghpur-Chhindwara road. They should prove useful as a paint material.

Both red and yellow ochres are used locally for colouring houses whilst the red ochre is also used for dyeing cloth.

Salt.

In the valley of the Purna river in Berar, there was formerly a salt industry dependent upon brine obtained from wells sunk in

the alluvium, the brine being found at a depth of 90 to 120 feet with a head of 15 to 20 feet. The brine was evaporated by solar heat in shallow pans. The centre of the industry was Dahihanda in the Akot tahsil of the Akola district. In 1885-86 there were four hundred wells, yielding to Government a revenue of Rs. 24,000; each well produced about 20 maunds of salt per mensem.

A certain quantity of salt is obtained as a bye-product in the manufacture of carbonate of soda from the brine of the Lonar lake in the Buldana district of Berar. It has also been noted that beneath the alluvial deposits of Western Chanda is a deposit of saliferous sand or clayey sandstone. The salt appears as an efflorescence, and two samples gave an average of 85·23 per cent. NaCl and 13·94 per cent. $MgSO_4$.

Soda.

In the Deccan trap basalts near the village of Lonar, in the Buldana district, Berar, is a circular crateriform hollow 300 feet deep and about a mile in diameter, and probably of volcanic origin, although views differ as to its exact mode of formation. This hollow is occupied by a shallow lake, the waters of which contain a large proportion of carbonates of soda, which crystallise out on the evaporation of the lake during the hot season and are used in the manufacture of glass and soap. According to one estimate in March, 1910, when the maximum depth of the lake was 2 feet, the water contained 2,000 metric tons of sodium carbonate, whilst the upper layer of the lake mud to a depth of 1·5 metres contained about 4,500 tons. Six varieties of salt are prepared, of the following range of composition :—

	Per cent.
Na_2CO_3	16·90 to 11·67
$NaHCO_3$	33·18 to 8·58
NaCl	*nil* to 71·11

The ratio of carbonate to bicarbonate corresponds closely to that for the mineral trona or urao.

The rights to work the lake were formerly let out on short-period contracts, and the output from 1909 to 1913 was about 450 tons: but in 1916 the Pioneer Alkali Works, Ltd., of Bombay, acquired the concession and in 1923 produced 600 tons of carbonate of soda. The output in 1924 was 20 tons; 1925—35 tons; 1926—

100 tons. The company went into liquidation in 1927. The rights for working the salts were auctioned for Rs. 700 in 1929, for Rs. 700 in 1930 and Rs. 100 in 1931. The production for 1931 is given as *50 khandies* (1,000 *maunds*). A triennial lease was given in 1932 for Rs. 500. Records of production of soda are not available for the years after 1931.

The occurrence of *reh* at Paunar in the Wardha district has been noticed. It is used for washing clothes and making soap.

Steatite.

Steatite (talc, soapstone, potstone) has been found at several localities in the Central Provinces, usually in the Archæan terrane. The best known locality is the Marble Rocks near Jubbulpore, where the steatite forms steeply dipping pockets in the Dharwarian dolomites. This steatite is slightly schistose, and varies from white to pale sea-green in colour. The deposits yield several hundred tons of steatite annually (*see* page iv), and one of the concessionaires has established at Jubbulpore a special plant for grinding the mineral, which is marketed in the powdered form. There are also deposits at Gowari and Lalpur to the south of the Narbada and near Rupaund on the Katni-Bilaspur branch of the Bengal Nagpur Railway.

Potstone and steatitic schist—probably of Dharwarian age—have been reported from several localities in the Bhandara district, whilst at Jambal Ghat in the crystalline area of Chanda is a dark-coloured potstone formerly used for carving into idols and household vessels. Similar rock from near Kilekora (20°41′ : 81°2′) in the Drug district is also worked for making utensils.

Soapstone has also been reported from near Wun; the geological association of this occurrence is unknown, but it must be with post-Archæan rocks.

Tungsten-ore.

The only known occurrence of wolfram in this province is that discovered at Agargaon in the Nagpur district in 1907. The wolfram occurs sparsely scattered in veins and stringers of quartz interbedded with mica-schists and tourmaline-schists of Dharwar age. The veins, however, are small, and the total amount of wolfram obtained appears to have been some 3 or 4 tons. Traces of scheelite have been found in association with the wolfram.

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MISCELLANEOUS NOTE.

Quarterly Statistics of production of Coal, Gold and Petroleum, in India and Burma: April to June, 1939.

Coal.

—	April.	May.	June.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	23,823	26,744	23,128	73,695
Baluchistan	779	2,528	1,043	4,350
Bengal	623,626	615,562	572,685	1,811,873
Bihar	1,252,226	1,226,891	1,142,183	3,621,300
Orissa	2,934	3,476	3,659	10,069
Central Provinces	131,059	146,347	144,888	422,294
Punjab	19,591	20,802	17,858	58,251
TOTAL	2,054,038	2,042,350	1,905,444	6,001,832

Gold.

—	April.	May.	June.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,141	8,416	8,130	24,687
The Champion Reef Gold Mines of India, Ltd.	5,780	5,967	5,779	17,526
The Ooregum Gold Mining Company of India, Ltd.	4,502	4,517	4,511	13,530
The Nundydroog Mines, Ltd.	7,629	7,832	7,579	23,040
TOTAL	26,052	26,732	25,999	78,783

Petroleum.

—	Crude Petroleum.	Total gasolene from natural gas.*
	Gallons.	Gallons.
Assam	5,963,107	*Nil.*
Punjab	6,995,560	129,613
TOTAL .	12,958,667	129,613
Burma	68,057,932	2,971,689

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

CYRIL S. FOX.

MGIPC—M—VIII-1-11—27-11-39—820.

FIG. 1. SERPENTINE. WESTERN END OF CHROMITE EXPOSURE, KANKAULI. ORDINARY LIGHT. (× 24).

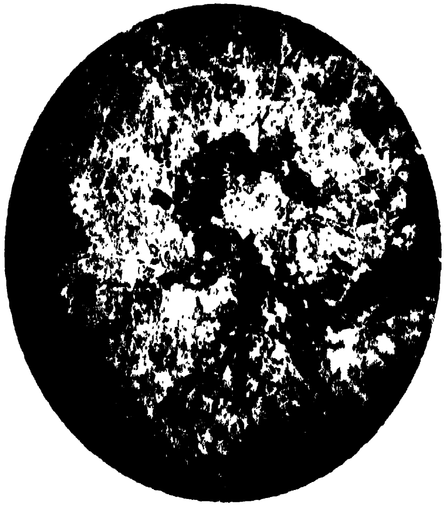
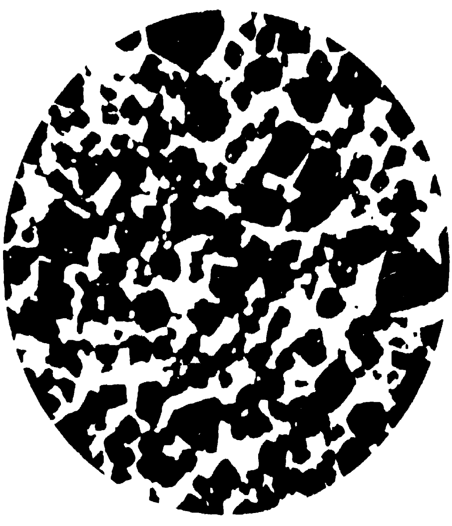


FIG. 2. SERPENTINE. JANAULI STREAM. ORDINARY LIGHT. (× 24).



S N. Das, Photomicros *G. S. I., Calcutta*

FIG. 3. GRANULAR CHROMITE WITH INTERSTITIAL SERPENTINE. ORDINARY LIGHT. (× 24).

FIG. 4. MASSIVE CHROMITE. ORDINARY LIGHT. (× 24).

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA

Part 4] **1939** [December

COAL IN THE MIRZAPUR DISTRICT, UNITED PROVINCES, AND IN THE ADJOINING PARTS OF THE SINGRAULI COALFIELD, REWA STATE, CENTRAL INDIA. BY A. L. COULSON, D. Sc., D.I.C., F.G.S., F.N.I., *Superintending Geologist, Geological Survey of India.* (With Plate 22.)

CONTENTS

I. INTRODUCTION.

"Statesman", 6th May, 1939.

An article in the Delhi edition of the "Statesman" of the 6th May, 1939 (page 6,column 7), indicated that the long known coal deposits of Kota (24° 6′ : 82° 45′) in the Mirzapur district of the United Provinces had been the subject of a report by Dr. V. S. Dubey, who had been carrying out a mineral survey of the United Provinces at the instance of the Local Government.

"Statesman", 9th May, 1939.

The following notice appeared in the "Statesman" of the 9th May, 1939:—

"Dr. V. S. Dubey, who has been carrying out a mineral survey of the United Provinces at the instance of the provincial Government, in the course of his report on the work done in the last few months, says that a deposit of coal occurs in the south-west of Mirzapur district in Singrauli close on the boundary of Rewa State.

The discovery of coal in this area was first made by Captain Wroughton in 1840. Here, four bands of coal aggregating 4 feet 9 inches in thickness were found in a total thickness of 6 feet 3 inches of strata. For a number of years mining was carried on and coal was sent on bullocks to Mirzapur where it was sold for use by a steamer plying on the Ganges.

After a few years of stoppage, mining was resumed in 1896 when about 1,000 tons of coal was raised. With the advent of coal which brought them cheap coal this adventure was given up."

Dr. C. S. Fox, 11th May, 1939.

The following is an extract from a letter written by Dr. C. S. Fox, Director, Geological Survey of India, to the Secretary to the Government of the United Provinces, Lucknow, on the 11th May, 1939:—

"The Geological Survey of India, initiated in 1845, has for over ninety years quietly made a systematic geological survey of the greater part of this country and carried out special investigations of coal and other mineral deposits. All this information is available in our office and much of it has been published in our Records and Memoirs, and it will be of interest to the United Provinces Government to consult pages 176 to 182 of volume LIX of the Memoirs of the Geological Survey of India (published in 1934) which deals with the coal deposits near Kota in the Mirzapur district. This occurrence of coal has recently, judging by the article in the Delhi edition of the 'Statesman' of the 6th May, 1939 (page 6, column 7), been the subject of a report by Dr. V. S. Dubey, who has been carrying out a mineral survey of the United Provinces at the instance of the provincial Government.

It was very unfortunate that the Kota mines were under water when we examined that area, and for this reason we were unable to give actual details of the quality, extent and resources of coal there. However, Dr. Dubey found the situation exactly the same, but this does not seem to have prevented him from visualizing a great coalfired power scheme and arriving at so low a figure as 2½ pies as the probable cost per electrical power unit. Dr. Dubey's objective—to secure the attention of the United Provinces Government for further exploration

of this coal area—is quite evident and justified perhaps from a zealous point of view, but when it is remembered that the Kota coal is a small fraction of a larger area of coal bearing strata, which extends into Rewa State, and has coal seams of known quality and abundance the danger of competition is evident, especially as the Kota scheme aims at putting a hydro-electric project in Rewa State at a disadvantage. It is unnecessary for me to go further into this matter, but as the United Provinces Government may perhaps require advice on other geological questions of a similar nature I write to say that my department will be pleased to help if we are consulted."

"Daily Telegraph", 11th May, 1939.

The following appeared in the London "Daily Telegraph" of the 11th May, 1939:—

"*India.*

NEW COALFIELD DISCOVERED.

From Our Own Correspondent.

Calcutta, Wednesday.

Importance is attached to a discovery of a seam of coal in the United Provinces, about 90 miles south of Mirzapur town.

This is probably an extension of the good-class coal seams which are supplying most of the fuel to the Indian railways from certain districts of Bengal and Bihar."

"Hindustan Times" 22nd May, 1939.

The following article by Mr. M. L. Misra, M.Sc., Ll.B., occurred in the "Hindustan Times" of the 22nd May, 1939:—

"COAL IN MIRZAPUR.

The news of the discovery of coal in Mirzapur is very pleasing indeed. That the coal seams extend over an area of 15 sq. miles and are capable of yielding 2,500,000 tons of coal per square mile, that the coal is of good quality and has remained unexploited simply due to the fact of its being away from the railway line, and that power can be supplied through it at the rate of $1\frac{1}{2}$ pie per unit, really makes one feel very jubilant. As a result of work by the U. P. Mineral Survey it has been found that 'the coal-bearing rocks are Barakur shales and sandstones which overlie the Talchir sandstones and shales'. This information is really academic and perhaps an improvement over the work already done by the Geological Survey of India. For this information our thanks are due to the U. P. Mineral Survey.

As one who is interested in such discoveries, I might suggest that very intensive investigations are needed in order to know the exact quality of this coal. The mere fact that 'the Barakurs contain a large quantity of coal in thick coal seams, though the quality of coal is variable, the percentage of the carbon is sometimes so low that the coal passes into mere carbonaceous shale by the large admixture of clay', Wadia, coupled with the knowledge that the coal seams even though capable of yielding $2,500,000 \times 15$ tons of coal have been lying as a waste for such a long time—from 1878 to 1939 under the British regime, throws a great amount of doubt on its quality or quantity.

The Barakur coal seams are noted to overlie seams of fireclay which is often found as an under-clay in the coalfields. The present coal also belongs to the same age and as such is most likely to contain layers of fireclay. Unfortunately the report that appeared in the press about the presence of coal is silent on this point. I hope those in charge of the Survey will not forget this point. The Ceramic and the glass industries of these provinces are solely dependent for supply of fireclay on the other provinces like Bihar and Central Provinces. A study of these fireclays, if at all they are to be found in the South Mirzapur district, along with the coal, will greatly help the abovementioned industries in the province. It is hoped that the Mineral Survey will surely oblige this industry too."

Dr. C. S. Fox, 30th May, 1939.

As a result of the publication of Mr. Misra's article, Dr. C. S. Fox, Director, Geological Survey of India, wrote to him as follows on the 29th/30th May, 1939 :—

"When you wrote 'Coal in Mirzapur', presumably after seeing the report of the U. P. Mineral Survey, perhaps you had not had access to the Geological Survey of India Memoir, Volume LIX (1934), on The Lower Gondwana Coalfields of India (read pages 176 to 182).

I should be very much obliged if you would consult the above publication so that you can gauge for yourself the extent to which the U. P. Mineral Survey may have improved upon the work of the Geological Survey of India, or derived its information from us.

I would add that it is a well-known rule (see page 343 of the above Memoir) that a seam of coal one-foot thick contains a million tons per square mile where lying flat, so that the 4-foot seam *assumed* by the U. P. Mineral Survey would hold 4 million tons per square mile, without allowing for losses in working.

Furthermore, in the Statesman Engineering Supplement of March 15, 1939, page 12, in an article on 'Mineral Production in India and Burma', I have specially dealt with the generation of cheap electricity in a coalfired station and also discussed the subject of Mineral Surveys of Provinces. I think you would find this article of interest."

"National Herald", 7th May, 1939.

The following is an article which appeared in the "National Herald", Lucknow, of the 7th July, 1939 :—

"ELECTRICITY FROM COAL.

AN ECONOMICAL SCHEME FOR UNITED PROVINCES.

By Prof. V. S. Dubey (Benares Hindu University).

The question of generation of hydro-electric energy from the Chachai Falls in Rewa State and its transmission to Allahabad district for the Eastern Grid has been before the Government of the United Provinces for some time.

Recently, a committee has been appointed to go into the scheme and to report to Government about it. A good deal of this power is to be utilised for pumping water for irrigation. A geological survey of the district of Mirzapur has led the

writer to the conclusion that it is possible to generate power at a very cheap rate at the coalfields of this district which are lying useless at present. It is not possible to transport coal without cheap means of communication like railways. These coalfields being situated about 90 miles away from the road, there is no chance of their development in the near future. But it is quite a feasible proposition to turn the coal into electric energy and transmit the energy to any desired distance. The cost of transmission of electricity is very small.

PRODUCTION COST.

As regards the costs of production of power at the Chachai Falls and at the coalfields, there are two points to be considered, that is the staff, and interest and depreciation; which are almost the same in both the cases. But, in the case of a hydro-electric plant we have to invest a very large amount of money in dams and other constructions, and thus the chief item of cost in the production of electricity is the interest and depreciation on the money spent in these constructions, while in the case of the steam-generated power the cost of coal is the most important factor.

The question of producing power from the Chachai Falls have been studied by Sir William Stampe, but he also has not considered this alternative source. It is the intention of this note to work out the alternative proposal for generating power.

UNTAPPED SOURCE.

The district of Mirzapur is fairly rich in coal, a considerable portion of the coal bearing area being included in the district. This area extends to hundreds of miles to the west in Rewa State, but, being away from the railway, it has not been developed at all, nor has it been paid any attention. For a long time to come there is no chance of its development, unless the railway lines are extended. Till now it was difficult to approach this area as a man had to walk about 50 miles before reaching this locality. Though the coal cannot be transported on account of lack of communications, it can very well be turned into electric energy which can be transmitted to Mirzapur town from where it can be distributed for the Eastern Grid. If a power house is built just at the coal fields, a transmission line of 90 miles will be sufficient to bring the power from this place to Mirzapur from where this energy is to be distributed as mentioned above to Eastern U. P.

THREE MAIN POINTS.

Now, we shall look into the question of the cost of generation. As mentioned previously, the coal is not being worked at present, neither is there any possibility of its being developed in the near future. The amount of coal is appreciably large. So in one way, this coal, for a long time to come, has as little value as the energy wasted from a water fall as is being now done at the Chachai Falls. To develop electric energy from a water fall would require a large amount of initial investment such as for putting a big dam; but the development of a coal mine does not cost so much. I am of opinion that about a lakh of rupees is more than sufficient to develop any good coal mine in this area.

While calculating the cost of generation we have to consider three main points, namely, fuel, interest and depreciation on the plant; and labour, technical and non-technical.

WORKING COST.

As regards fuel, about two lbs. of coal are required to generate one unit of electricity. The price of coal varies greatly in different places. If the power house is to be placed at the coalfields the cost of the coal will be very small but still, assuming the cost of raising the coal to be one rupee and the royalties to the State to be annas eight per ton, the total cost of coal at the power house will not amount to more than a rupee and a half per ton. For our calculations, we may assume it to be a maximum of two rupees per ton. Thus the cost of coal—2 lbs. required to generate one unit of electricity will amount $\frac{1}{3}$ of a pie nearly.

The other item of cost is interest and depreciation. The price of the whole plant including boilers and turbines will work out to be about 0·150 per kw. generated. Assuming the interest to be 4 per cent and depreciation at 8 per cent on the capital together with the repairing and renewal charges, this item would amount to about 0·18 per kw. that is for 8,760 units. So the interest and depreciation works out to be $\frac{1}{3}$ of a pie per unit.

As regards labour, most of the work is automatic and we require only a few persons of the higher staff. The cost of labour per unit of electricity will depend upon the size of the plant; the bigger the power house less the cost.

If we assume our power house to be of 30,000 kw. capacity and the monthly charges for labour, technical and non-technical, to be Rs. 6,000—which is the maximum limit, the cost of labour will work out to be about $\frac{1}{18}$ of a pie.

Thus the cost of generation of electric energy per unit at the coalfields will be as follows :—

Fuel $\frac{1}{3}$ of a pie per unit ; interest and depreciation $\frac{1}{3}$ of a pie ; labour $\frac{1}{18}$ of a pie and unforeseen and other charges as water, etc., $\frac{2}{18}$ of a pie ; in all one pie per unit.

Thus we see that the cost of electric energy generated will amount to one pie per unit, which is as cheap a rate as can be obtained at any hydro-electric station.

TRANSMISSION.

Now comes the question of transmission. The cost of the lines which will be capable of carrying up to 30,000 kw. at a very high voltage, say 100,000 or so, will amount to about Rs. 10,000 per mile. By a transmission line of about 90 miles we can reach Mirzapur. The cost of these 90 miles would amount to about 9 lakhs of rupees. If we transmit 30,000 kw. power and assume 4 per cent as the interest and 3 per cent as the depreciation charges on the capital spent for the line, the total amounts to 7 per cent or Rs. 63,000 per year on the investment of Rs. 9 lakhs. If we transmit 30,000 kw. power, the transmission cost per unit will amount to about $\frac{1}{20}$ of a pie. Even if the load factor be 50 per cent, the transmission cost will not amount to more than $\frac{1}{10}$ pie per unit.

Thus, it will be possible to deliver power at Mirzapur roughly at 1·1 per (? pie) per unit. In any way, taking all the figures very liberally, the cost of power delivered at Mirzapur will not be more than 1·25 pies per unit. If we want a smaller

plant, say of about 5,000 kw. capacity, the cost of generation would also go higher—for 5,000 kw. plant being about 2 pies per unit.

On the other hand, we require more than 30,000 kw. power for the Eastern Grid, either we can build a bigger power house or add more units as the demand for the power increases in future. Here we have got a great elasticity. With the large amounts of coal available in the coalfields we can have a power house right from a small one to a very big one without any difficulty. In the case of hydro-electric station we have not got that elasticity. The power house cannot go below a particular capacity nor can it go up if the size is fixed and the minimum investment will amount to about Rs. 75 lakhs. If need be, we can start with one of 10,000 kw. requiring a total capital of Rs. 15 lakhs for building the power house and Rs. 10 lakhs for the transmission lines.

Now the problem is whether the interest and depreciation on the capital required to build the dam per kilowatt capacity is more or the price of coal required to generate a kilowatt. If we assume the cost of the whole construction to be about Rs. 75,00,000 that is for a hydro-electric station of 30,000 kw. capacity—it works out to be Rs. 250 per kw., while the interest and depreciation at 6 per cent amounts to Rs. 15 kw. per year. At 2 lbs. per unit, the coal required for the whole year comes to about 17,500 lbs. or about 8 tons, the cost of which at Rs. 2 per ton being Rs. 16. Thus, we see that both these items work out to be almost equal.

Now in calculating the price of coal as at Rs. 2 we have assured a royalty of As. 8 a ton to the State. Thus we see that as an economic proposition the electric energy can be produced as cheaply from the coalfields as from hydro-electric station at the Chachai Falls.

If a good part of this electricity is to be utilised for pumping water for irrigation purposes, the load will be only seasonal in summer months when there is demand for irrigation water, the load factor will be very low, which in no case can be higher than 33 per cent. As the money on constructions has been already invested and the staff will be retained throughout the year, the expenses will be the same whether the current is used throughout the year or for only three months. Therefore, the whole of the expenses will have to be borne out of the three months' consumption. So the ultimate rate of current would come to $4\frac{1}{2}$ pies instead of $1\frac{1}{2}$ pies per unit.

THERMAL STATIONS.

From the point of view of intitial investment and in view of the less cost of generation, it seems better to have the thermal station at the coalfields than to have the hydro-electric station. The total investment for the thermal station of 30,000 kw. capacity and the expenses for transmission will together amount to not more than Rs. 40 lakhs as against a crore in the hydro-electric scheme. In India, though we have not got sufficient supply of coal we need not care so much about preserving this deposit which lies too far away from the means of convenient transportation.

RECOMMENDATIONS.

In order to complete the scheme it is essential that proper boreholes should be put down and the quantity of coal assured around the place where it is intended

to locate the power house. For selecting the location of the power house the question of water supply has also to be considered. The Rewa State is also considering the same question and it may be possible to utilise the same power house for the need of the United Provinces as well as the State.

If the power could be delivered at something like 1·5 pies per unit at Mirzapur it will be possible to supply the same to the towns in eastern United Provinces at something like 2 to 3 pies per unit. And with this rate of power, it is possible that many industries may be started.

In this eastern grid attempts should be made to utilise at least 50 per cent of the power for industrial purposes and 50 per cent for pumping load for irrigation. If half the load is industrial with a load factor of 80 to 90 per cent, and half irrigational with a load factor of 30 per cent the average load will go up to 50 to 70 per cent."

II. GEOLOGICAL OBSERVATIONS.

Former reports mostly not easily available.

In order to chasten hopes of wonderful deposits of coal that have definitely been raised by the publication of the foregoing optimistic newspaper articles and reports, it seems eminently desirable that previous observations and opinions regarding this coal at Kota (24° 6′ : 82° 45′)[1] and the adjoining part of Rewa State, all of which are included under what is generally known as the Singrauli coalfield, should be made easily available. The earliest reports by Captain Wroughton and D. Smith are now not easily accessible. Mallet's important progress report of 1870-71 is not available to the general public. It is interesting to note here that in Mallet's time, the area was referred to in the Annual Report of the Geological Survey of India as the Kota coalfield. Whilst Oldham's and Ball and Simpson's observations are still easily available, K. P. Sinor's work was published in 1923 but in a publication of Rewa State again not everywhere available. My own observations are published in the form of a geological report to the Central Indian Coalfields railway and again are generally inaccessible. Dr. Fox's observations, however, include extracts from Sinor's and my reports and may easily be consulted.

[1] Only the old maps are available and for ease of reference, the longitudes given in this paper are those of the old Standard sheets. They require a correction of approximately − 3′ to make them accord with the most recent value of the geodetic longitude of Madras Observatory. Most of the places mentioned in this paper will be found on the following four one-inch standard sheets—476 C. I. and Raj. (9 Rewah Survey ; 63 L/4 and 8) ; 477 C. I. and Raj. (19 Rewah Survey : 64 I/1 and 5) ; 186 U. P. (8 Rewah Survey ; 63 L/12 and 16) ; and 187 U. P. (18 Rewah Survey ; 64 I/9 and 13). See also Plate 22.

Captain Wroughton, 1840.

The following is the account given in *The Engineer's Journal, Railway, Public Works, and Mining Gazette, of India and the Colonies*, Calcutta, II, No. 19, p. 340, (October 1, 1859) :—

"COAL IN THE NORTH WEST.

Some doubts having been expressed as to the success of any attempts to find good Coal in the North West, a Correspondent of the *Friend of India* thus writes :—

'I think I will satisfy you that the North West possesses as good a quality of Coal as the lower provinces, and that it need not depend upon Raneegunge and Beerbhoom for a supply of the mineral equal to their wants, if the same facilities were in existence in the North West for the removal of the Coal as at Raneegunge.

The Singrowly mines to the South of Mirzapore offer an inexhaustible supply of Coal for the N. W. and which has been pronounced to be of an excellent quality. This field was discovered in 1840 by Captain R. Wroughton, Revenue Surveyor. An analysis of the Coal shows it to contain a very small proportion of ashes promising at a greater depth a superior quality of the mineral.

Specimens.	Volatile matter.	Carbon.	Ash.
B. Pit No. 2	44·2	54·3	1·5
C. Pit No. 5	42·5	55	2·5

This Coal taken from near the surface cannot be expected to equal that taken from the comparatively deep pits of Raneegunge, but if a pit were sunk to a moderate depth in all probability Coal of a quality would be found to answer well for locomotives as well as for Steam Boats. There is good and bad Coal in all Coalfields, but good Coal cannot be obtained near the surface nor can good Coal be obtained without a proper search being made for it. Captain Wroughton in making known his discovery, says, "I have the honour to report for the information of the Sudder Board of Revenue, N. W. Provinces that in prosecution of the Survey of Purgunnah Singrowly of this district I have discovered a Coal field, extensive, near the surface, and producing mineral of an excellent quality." Coal found near the surface is a certain indication that it is also found at some distance from it, and as Captain Wroughton says that the Coal near the surface is of an excellent quality, the same rule would hold good here as in all other Coalfields. "The deeper the better the Coal." Indications of Coal have been found within about 48 miles of the River Ganges in a much more convenient situation than the place discovered by Captain Wroughton.

At present a lakh or two of Maunds could be transported yearly on bullocks to the Ganges, but if it ever be intended to supply the Rail in the N. W. Provinces at a rate not exceeding that of Calcutta, a Rail must be put down to the Coalfield, as the quantity required for the Rail alone will amount, when the whole line is opened, to at least one hundred thousand tons, and the Government and private Steamers on the Ganges will also require a large quantity. A Railway constructed by the E. I. R. Company from their present line to the Coal field would save them lakhs of Rupees per year, and the saving in the cost of Coal would in the course of

10 or 12 years pay for the complete construction of the Rail. But here is a splendid Coalfield neglected owing to the total absence of all enterprise and energy in the country. If good coal were found on the surface, there would not I suppose be wanting parties to avail themselves of it, but the mineral like all other articles in the world to be found good must be paid for.' "

Wroughton's optimism understandable.

Wroughton's optimism regarding the coal is well understandable when one remembers the period at which he made his discovery. In the cold light of modern requirements, something more is necessary to prove the value of a recently discovered coalfield than glowing statements and two analyses of good surface specimens.

D. Smith, 1868.

The following account by D. Smith of the workings at Kota is taken from *Sel. Rec. Govt. India, Home Dept.*, LXIV, Calcutta, pp. 92-95, (1868) : —

" Passing Gurwhar south towards Kotah, when opposite the village of Ceirwah, in the closely adjacent hills to the west, is first shown the light grey soft sandstone I have always seen as the covering of the coals of India. From this point Kotah is distant 6 miles to the south, and within half a mile of the boundary of Shaipoor Sigrowlee.

Near to Kotah, a mine has been opened and worked for some years, although not extensively, on the only seam of coal as yet discovered in this field. When I was there, the mine was inundated, so I could not go in to see it. I employed men to sink a shaft on the vein, with the view of satisfying myself by personal inspection of its thickness and general features ; but, after a week's work, I was convinced it would require three weeks or a month to sink to the seam—a longer time than I could afford to wait. I was, therefore, obliged to be content with the following section of it, supplied me by Mr. Burke, the Superintendent of the colliery, and which I believe may be relied on as correct :—

Section of Kotah vein below sandstone covering.

	Ft.	In.
Light colored plastic clay	1	0
Sandstone with slate, alternating	7	0
Clay slate, micaceous	0	6
Bituminous shale	1	6
Coal	1	0
Bituminous shale	0	8
Coal	1	6
Very hard sandstone, Kotah vein	0	1
Coal	1	6
Clay slate	0	6
Coal shale	0	3
Coal	0	9

This section shows the vein at Kotah to be not favourable for working, as the aggregate of the coal workable is but 4 feet, to obtain which the 10 feet of mixed

ground lying immediately over it has to be removed,—an undue proportion of waste even when carried on by open patchwork, and much in excess to admit of fair profit in an underground working, where the spoil has to be wrought by a more expensive process, and nearly the whole of it conveyed out of the mine. As Mr. Burke assured me, it could not be made available as the roof of the mine, for when tried, it quickly gave way, falling in masses, endangering the lives of the miners, some of whom were killed and several seriously injured during the attempt to save the heavy expense of its removal.

Now, although the section given doubtless represents correctly the form and condition of the seam at the spot where it has been worked, I am of opinion that many localities much more favourable might have been fixed on in the neighbourhood for opening a colliery than that selected for the Kotah mine.

The form of the surface, as a rule, I do not mean without exception, is indicative of what may be expected under it; undulations and the depressions above, have most commonly corresponding irregularities in the strata below; and to the fact of the Kotah mine having been opened in such a position (that is, in a hollow between hills), is due, I believe, to the unfavourable features presented by the seam.

I am confirmed in this view by tracing the same vein into Shaipoor Sigrowlee, about six miles in a direction south-west from Kotah, where a section of it is exposed in the hillside at Toorah, about 150 feet perpendicular above the plain, and nearly opposite the village of Nowah Nuggur. There the vein, in sound undisturbed ground, is nearly nine feet thick, of clean coal, with not more than a foot of black shale between it and the sandstone; and if the coal was sought for at Kotah, in a like position, that is, under the hills and not in the hollows between them (for the 'dip' being northerly the coal at Kotah lies below the level of the plain) little doubt can exist the seam would then be found in one solid bed, and not divided into layers so unfavourably exhibited in the Kotah mine.

At Kotah, the coalfield is about 1½ mile in width, from east to west, that is, so much of it as lies within British Sigrowlee. To the north it reaches to within two miles of Oondhee or about ten miles, and although not free from faults and dislocations, some of them important, it would be as a whole a valuable field if it had easy communication with market; the present heavy cost of transports seriously limiting the working; there being no means of conveyance save that afforded by pack bullocks, each carrying three maunds to Mirzapur—a journey occupying about twenty days.

In quality, the Kotah coal is good; it burns freely, with a clear flame, leaving a white ash, but will not coke by the ordinary means. In a closed retort it may, like the coals of the Raneegunge district, be so converted; but that is a mode that cannot be profitably adopted unless manufactories were established, requiring large and highly heated furnaces, the spare heat from which could easily be applied to the retorts.

While staying at Kotah, I examined the coalfield into Rewah, going westward to Pudree, a distance of about 18 miles. The coal extends the whole way and beyond, but not in a continuous field; it may be more correctly described as a succession of basins, almost each undulation of the surface causing an interruption.

At Pudree a mine was in work, not by shaft but open patch, the coal being 21 feet in thickness, abruptly stopped to the north by the upheaving of the lower

measures about 500 yards from the mine, this excessive depth of coal proving this to be in one of the basins spoken of.

The Rajah of Rewah claims a right to the minerals in his territory, and I was informed is very jealous of Europeans having any settlement there,--a feeling that will prevent a renewal of the existing short license for working at Pudree.

This coalfield geologically is one, the largest portion of it being held in the independent territory of Rewah; the next in extent being in Shaipoor Sigrowlee, owned by the Rajah of Sigrowlee, who I was told, holds there a large tract of country comprising about 700 villages; the third and least section of it is within British Sigrowlee, likewise possessed by the same Rajah, who has let the whole of this portion of the field to Messrs. Hamilton and Co., of Mirzapur, under an interminable lease "

Smith far less optimistic than Wroughton.

It will be seen that D. Smith was for less optimistic than Captain Wroughton. Even in 1868, the mine was flooded and Smith found it impossible within the time at his disposal to sink a shaft in order to see the width of the seam that was supposed to have been worked. The section supplied by the Superintendent of the Colliery was far from encouraging, as Smith noted; the aggregate thickness of the four seams was 4 feet 9 inches with some 1 foot 6 inches of shale, slate and sandstone intermixed and 10 feet of similar material above it under a sandstone covering. Smith mentions the thick seam at Naunagar (24° 7′ : 82° 39) in Singrauli to which I refer later. He was obviously disappointed with such of the Singrauli coalfield that is now within the borders of the Mirzapur district. The "Pudree" mentioned by Smith as the site of another mine is Parari (24° 12′ : 82° 35′), 12 miles north-west of Kota; it is not 18 miles west of Kota as stated by Smith.

F. R. Mallet, 19th June, 1872.

Practically no notice has been given in the past to the examination by F. R. Mallet of the coal-seams in that part of Rewa adjoining the Mirzapur district during the field seasons 1868-69 and 1871-72. I myself was unaware of Mallet's work at the time of my visit in 1923. I cannot find any published reference to Mallet's work on the coal except the following short notice which appears in the Annual Report for 1872 (*Rec. Geol. Surv. Ind.*, VI, Pt. 1, p. 2, (1873)—

"Mr. Mallet, who had, as reported at the close of last season, proceeded to the coalfields of Kota, on the southern borders of Mirzapur district, mapped out its limits. He notices some fourteen outcrops of coal, most of them, however, very thin and worthless; some two or three have a workable thickness of fair coal. All appear to be on about the same horizon, not more than two being seen in any cross section, the richer outcrops thus appearing to be only local."

Oldham mentions Mallet's reports when compiling his joint report on the geology of the Son valley [*Mem. Geol. Surv. Ind.*, XXXI, Pt. 1, (1901)], but does not deal with the area visited and described by Mallet. Mallet mapped on sheets 8 and 18 of the old Rewah Topographical Survey (186 U. P. or 63 L/12 and 16, and 187 U. P. or 64 I/9 and 13, respectively) and apparently handed in fair copies of both sheets.[1] Only sheet 8 is now available, but luckily that one is the more important in this connection as it borders the Mirzapur district near Kota. In spite of his voluminous writings, Mallet seems to have confined the published record of his work in this area to mineralogical descriptions of the gneiss of South Mirzapur [*Rec. Geol. Surv. Ind.*, V, Pt. 1, pp. 18-23, (1872); *op. cit.*, VI, Pt 2, pp. 42-44, (1873)], and to have left the coal-bearing Gondwana rocks severely alone. It seems eminently desirable that full extracts from the unpublished parts of Mallet's progress report for 1871-72 should be given as he obviously spent much time in the area, examining it in great detail. Accordingly I offer no apology for the length of this sub-section.

General description of the area.

Mallet commences his progress report with the following general description of the area. His progress report is in manuscript and in places his handwriting is difficult to follow.

"A glance at the maps accompanying the present report (Sheets 8 and 18 Rewah Survey and part of S. W. of Mizapur) show that of the included area, the south eastern portion is occupied exclusively by gneiss, to the north and west of which there is a broad fringe of Talchers. The latter varies much in width and narrows towards the south east until the Talcher beds disappear and the higher rocks are in contact with the crystalline series.

Beyond the fringe of Talchers and resting on them, the Barakur sandstones come in—to the north they occupy a belt some six or eight miles broad, north of which Talchers and gneiss are again found and beyond them there is the great spread of slates, etc., which extends nearly up to the Sone.

At some little distance, generally a mile or two, from the boundary with the Talchers, the Barakurs rise into an escarpment much cut up by deep ramifying gorges in which most of the observed coal outcrops have been found. The plateau to the north is some hundred feet higher than the Talcher area, and but a trifle higher than the country occupied by the slates. To the west [N. W. of Kota (24° 2′ : 82° 35′)] a similar escarpment is flanked by numerous outliers, and from the edge of which these rocks stretch westwards for a long distance.

[1] Some of sheet 18 described by Mallet lies now within Surguja State, Eastern States; but all coal outcrops mentioned in his report occur either in Rewa State or in the Mirzapur district.

To the south again the sandstones rise into flat-topped or sloping masses of hill which greatly exceed those to the north in altitude. The thickness of strata exhibited here is also much greater and the relations of the upper beds have not yet been determined with certainty. There is an abundant appearance of trappean rocks about here. It will be observed that both the Talcher and Barakur beds have a general dip away from the gneissose area through which the Rehr flows a dip which is probably due in part (but, especially towards the south, only in part), to the original conditions of deposition."

Gneiss, amphibolite, and trap dykes.

The next part of Mallet's progress report is occupied with a description of the gneiss, which he states is exactly similar to the gneiss of Mirzapur he described in *Rec. Geol. Surv. Ind.*, V, Pt. 1, pp. 18-23, (1872). He states that "hornblende-rocks" are rarely met with in the north-west corner of sheet 8; but in the southern part of sheet 18, this amphibolite is common. In the adjacent sandstone series (Barakars) on sheet 18, trap dykes are common and no doubt also cut through the crystallines. The undoubted dykes in the coal-bearing series have an east and west trend, but so have the bands of amphibolite. Mallet found difficulty in distinguishing in the field between the trap dykes and the amphibolite.

Limestone, dolomite, wollastonite, corundum, and magnetite.

The next few pages of Mallet's progress report have been reproduced word for word in *Rec. Geol. Surv. Ind.*, VI, Pt. 2, pp. 42-44, (1873), and deal with the limestones and dolomites of the gneissose series. He gives analyses of these and refers to the occurrence of wollastonite in association with limestone occurring as inliers in the Talchirs. He also deals with the corundum of Pipra (23° 58′ : 82° 44′), later visited by Dr. J. A. Dunn (see page 464). Finally he mentions the occurrence of beds of magnetite in crystalline inliers.

Pegmatites, quartz-veins and quartz-reefs.

Mallet then deals with pegmatite veins, which he states are as frequent in the gneiss as in the Mirzapur area. He notes that small veins of white translucent quartz with large flakes of muscovite are common, generally running parallel to the strike of the foliation of the gneiss. Whilst these are seldom visible for more than a few hundred yards, larger quartz-reefs can sometimes be traced for miles and sometimes rise into hills some hundreds of feet high. Such quartz-reefs are most common in the gneiss near the boundary with what Mallet

terms the slate series (Transition rocks); he did not find any reefs in the slate series.

Breccia.

There is also a breccia found in places along the northern boundary of the coal-bearing rocks which is distinct from the quartz-reefs.

Gneiss-slate junction.

Mallet notes that the junction between the gneiss and the slates of the Transition series is ill-defined in sheet 8. He notes, however, that there is a gradual change in the character of the gneiss. He sums up by stating :—

"Assuming as is most probable that the gneiss and slates are really distinct series, it seems clear that although the gneiss may have undergone great metamorphism before the deposition of the slates, still there has been sufficient metamorphic action since that period, to obliterate the original lines of separation—the only boundary which can be drawn therefore as far as our present knowledge goes is a purely lithological one."

Slates.

Mallet notes that there is nothing special to be said about the slates in the area. He found in them a few trap dykes and one band of grey crystalline limestone.

Talchirs.

"The Talchers occupy a considerable area between the gneiss and Barakars stretching in one spread from Seyndoor [? Sendur (24° 12′ : 83° 0′)][1] on the Rehr to Amlia (24° 2′ : 82° 28′) and extending southwards as far as Bamarkho (23° 51′ : 82° 38′), a distance of about 40 miles in a straight line or along the curve of over 50. The breadth varies from a couple of miles up to 7 or 8. The group presents characters here similar to those so often described and to which I have alluded in my report for last year, p. 42. The boundaries with the gneiss are natural, all along (with one or two exceptions to be noticed hereafter) and sections showing the superposition of the Talchers are frequently obtainable, instances of which I have given in my other report.

In the north west part of sheet 8 there are two very much smaller patches of Talchers. In the larger of these near Gunwali (24° 12′ : 82° 33′), I observed one or two single beds of highly calcareous sandstone which have quite the aspect of limestone in their mode of weathering, resembling the sandstone of Fontainbleu. The smaller patch is greatly obscured by alluvium, the rock in fact being only seen at Tulda (24° 9′ : 83° 32′) and at the eastern end. The southern boundary and the western extension from Tulda are conjectural.

The elevation of the Solang (24° 12′ : 83° 36′) patch is considerably greater than of the Tulda one, there being a descent of at least 150 feet along the portion of the stream between the two occupied by gneiss. Both, however, like the great spread to the south, occupy the lowest ground *in the immediate neighbourhood*; hence the boundaries of the Talchers are generally found to correspond in some degree with those of the main alluvial spreads of the vicinity.

[1] I have inserted latitudes and old longitudes for convenience of reference.

The boundaries of the above patches are faulted in one or two places, but I will describe such cases along with the Damudar faults. The boundary between the Talchers and Damudas is not often seen in vertical section but where it is it is sufficiently well marked. Thus the upper part of Bonaoli Hill (24° 2′ : 82° 34′) is of rather coarse felspathic Barakur sandstone, while Talcher sandstone and yellow mudstone are seen all round the base. In ascending the hill undoubted beds of each series are seen within 20 or 30 feet of each other vertically. In the stream of Jhureunda (24° 3′ : 82° 33′) immense concretions (10 or 15 feet long) of a hard sandstone weather out from the softer mass of yellow Talcher sandstone. Such appear to be rather frequent in the higher beds of the Talchers just below the Barakurs. In horizontal sections where the dip is very low the line between the two series is not so clearly marked, although even on the scale of 1 mile to the inch there is seldom much difficulty in drawing the boundary from this cause. In places however it is greatly obscured by alluvium.

From Bamarkho eastwards as far as and beyond the edge of the sheet the Talchers are overlapped and the Barakurs rest directly on the gneiss. As the former occupy the lowest ground, the rice of the surface from Bamarkho to Bargar (23° 51′ : 82° 41′) is in itself probably sufficient to account for this."

Barakars.

Mallet's description of the Barakars is likewise quoted in full :—

"The lithology of the Barakurs in the present region is very much the same as what it appears to be elsewhere. The mass of the rock consists of coarsish felspathic sandstone in which occasional beds of coal and frequently of grey and black shale occur. The sandstone generally is a white rather coarse friable very felspathic rock, often containing grains of white quartz. Sometimes it has a yellow, red or mauve color due most frequently to superficial alteration, but sometimes it possess a red tint naturally from containing red felspar in large proportion. The ordinary rock is rather coarse, never *fine* grained apparently and sometimes coarse. Pebbly beds are not uncommon, the well rolled pebbles being chiefly of white quartz. Layers of shaly micaceous sandstones are sometimes seen. The sandstone is often highly ferruginous on the surface from atmospheric alteration and such rock is smelted to a trifling extent at Nige (24° 10′ : 82° 40′), Jhinghurdha (24° 12′ : 82° 45′), etc. In some of the nallas pieces of tolerably pure brown hæmatite are sometimes found, probably produced by segregation. Amongst the subordinate varieties of sandstone I may mention one met with in a stream S. of Muri (23° 51′ : 82° 34′), a conglomeratic rock, the rolled fragments in which are of Talcher sandstone.

The sandstones I suppose form fully 95 per cent. of the entire group, the other beds being very subordinate. The latter include grey, black and buff shales in which ill preserved vegetable impressions are often common.[1] Such shales are more than usually abundant in the Mear and adjacent streams near Dhari (23° 50′ : 82° 32′). There are also brick red and white porous shales, the colors being sometimes interbanded. The best section I obtained of these beds was on the S. W. side of Kupsoo

[1] In a marginal comment, obviously written in September, 1876, Mallet has noted that the upper, non-coal-bearing, sandstones, which are coloured Barakars on sheets 8 and 18 Rewah Survey, not improbably belong to a higher group of the Gondwanas.

Hill (S. W. of Bamarkho) where 60 or 80 feet of them mixed with some greenish grey shale, is seen resting on and covered by sandstone with trap above. Smaller bands are observable in other localities but they are not very frequent.

Stratigraphy; sheet 8.

The stratigraphy of the Barakurs is very simple. Along their southern boundary, they rest on the Talchers and in the area south of the Kachur nuddee are as nearly as possible horizontal. In the country to the east of this stream as far as the limits of the field in Mirzapur there is a gentle dip to the north which extends over the entire area with some local exceptions, as about Solang where the beds dip away from the Talchers. I am inclined to consider the present northern boundary of the field as having been the original one. In a previous report (68/9, p. 6) I have pointed out that the general level of the slate area in Mirzapur is some hundred feet higher than that of the gneissose country, the boundaries of the two formations being indicated by an irregular escarpment facing the south. Only roughly so however, for in places the gneiss extends some distance north of it. Now if the gneissose and Talcher country east of Haori Hill (24° 12′ : 82° 46′) were filled up with Barakurs to about the level of the Mirkowli plateau, the northern natural boundary of such addition to the coalfield would be the escarpment just mentioned, that is to say it would be a continuation of the present boundary of the actual field. Or conversely, if the Barakurs and Talchers in sheet 18 were removed, we should have a gneissose area bounded on the north by a continuation of the existing escarpment. I have already shown that there is some reason for supposing that the quartz reefs of this district are older than the slates; and if so, of course much older than the Barakurs and I believe that the reef between Haori and Jaraila Hills formed the edge of the slate area escarpment at the time the Barakurs were laid down and hence the boundary of the Barakurs themselves, the latter then stretching considerably to the eastward of their present limits. In a similar way the quartz reefs in Mirzapur sometimes form the edge of the existing escarpment; and in other places must have done so formerly before denudation in comparatively recent times had cut back the escarpment some distance north of them.

But admitting the above conclusion, there is still evidence of more or less faulting along the boundary in the crushed state of the rocks there. Thus in a little hillock N. of Jhinghurdha, the quartz schist at the boundary is completely smashed up into a coarse breccia whilst it shows nothing of the kind to the east away from it. To the west of Jaraila Hill (24° 13′ : 82° 39′), breccia is again seen in which besides fragments of the older rocks, the late Mr. J. G. Medlicott found blocks of sandstone containing Damuda fossils. These I was not fortunate enough to observe. The sandstone itself is sometimes altered along the immediate line of junction as in the corner N. E. of Kallar [? Kassar (24° 13′ : 82° 35′)], where there is a little hill of it on the west side of the stream. I think such faulting however is only local slipping along the boundary as a line of weakness, and perhaps it may not even be continuous all along.

There is another fault, also probably of trifling throw, which brings the Barakurs against the Talchers S. of Parari (24° 12′ : 82° 35′). Sections showing this are obtainable at the foot of the little hillock N. E. of the coal seam and in the stream close by It is apparently the same fault which brings the Talchers against

the gneiss at Tulda, continuing probably beyond Phulwari (24° 9′ : 82° 30′), where the Barakurs are again in contact with the latter ; but I have refrained from drawing it beyond Tulda until the ground to the west has been examined.

Sheet 18.

With the exception of the mass of hill S. E. of Bamarkho, where there is a dip to N. N. E., the post-Talcher sandstones in sheet 18 have a pretty steady dip to S. S. W. at varying angles up to 40°, the average being perhaps about 15°. The thickness of sandstones, amounting to some thousand feet, naturally led me to feel doubtful as to their all belonging to the Barakur group, but I was unable to fix upon any characters sufficiently distinctive to warrant a separation. There is indeed a complete absence of coal in the hills along the southern edge of the sheet, but in the country to the north, nearer to the Talchers I only found three or four outcrops. On the *tops* of the hills between Dhari and Kolwa (23° 50′ : 82° 41′) also I found no trap whilst such is abdundant in the gorges and low ground ; but as Mr. Medlicott informs me that trap is common in the higher group to the south, this fact must be taken as a merely local one.

There is also a physical feature which may be found connected with a geological distinction. The escarpment north of Kotah and Kuchuni (sheet 8) is only 400 or 500 ft. high ; but in following it southwards past Amlia (sheet 9), it suddenly rises in Dhiraoli Hill (sheet 19 ; 23° 55′ : 82° 59′) to double its former elevation and maintains this altitude southwards and eastwards to Dheka Hill. From Dhiraoli Hill two escarpments run, one S. E. with, as first mentioned, an elevation of over 1,000 ft., another S. W. with an elevation of some hundreds. It is therefore possible that the latter horizon marks the boundary of the two groups ; and this is the more likely from Gurwani Hill (24° 1′ : 82° 20′) which appears on the map to be an outlier from Dhiraoli plateau having been found by Mr. Medlicott to be of the higher group. If this be so, the upper part of Dheka Hill and the Hills to the south are probably of the latter rocks, the Barakurs being found only in the gorges and base of the escarpment.

Barma, Jhapi (24° 6′ : 82° 32′) and some other hills in the vicinity present an unusual feature in horizontally bedded rocks, in being some hundred feet higher than the palteau they fringe, and physically they seem to be outliers from the Dhiraoli plateau as well as from that immediately to the west of them. If the Dhiraoli plateau be of the higher group therefore, it is very probably that these outliers are also capped by them."

Coal outcrops on sheet 8.

I shall give first the outcrops of coal noted by Mallet on sheet 8 of the Rewa Topographical Survey (U. P. 186 or 13 L/12 and 16).

Tipajharia (24° 11′ : 82° 46′).

Mallet noted a few fragments of shaly coal in the gorge south-east of Tipajharia, but could find no outcrop.

The mines at Kota were choked with mud and water at the time of Mallet's visit, but the following section given to him by a

Mr. Jones of Dhoordhee who saw the mine when open. It differs somewhat from that given by Mr. Burke to D. Smith and already quoted (page 443)—

Kota (24° 6′ : 82° 45′).

"Sandstone of the ordinary felspathic type[1]

	Ft.	In.
Dark grey shale	2	0
Coal	1	0
Black shale	0	8
Coal	0	9
Black shale	0	6
Coal about	1	10

There is then perhaps 40 ft. of sandstone from the mouth of the mine down to the road, immediately on the south side of which in a nulla the section is continued :—

	Ft.	In.
Whitish felspathic sandstone as above Carbonaceous shale	0	4
Shaly sandstone	1	0
Felspathic sandstone in thick beds	12	0
Dark grey shale with plant marks	1	5
Coal	1	0
Buff micaceous shale—seen	0	4

Both seams are exposed in the stream west of Mr. Burke's bungalow, the upper at a point where two nullas meet and where an adit has been driven into the sandstone, the smaller one a little lower down where it has the same thickness of one foot and dips N. at 5°.

The main seam has according to Mr. Jones' section a thickness of 4 feet 9 inches, including 3 feet 7 inches of coal and 1 foot 2 inches of shale in two partings. A quantity of the coal was taken to Mirzapur on bullocks of Messrs. Hamilton Brown and Co. to whom the mines belong, for trial, and was pronounced on the railway rather superior to average Raneegunge coal. An assay of it gave—

	Per cent.
Volatile	25·4
Carbon	63·4
Ash	11·2
	100·0

Thin seams of siderite are frequent in the jointing, no doubt derived from the decomposition of pyrites. A large quantity of the coal is, however, stacked at the mouth of the mine (under cover) and has remained good for years. The one-foot seam has not been worked."

[1] This and the following sections are given in descending order.

Mallet records a few fragments of coal in the bed of the Balia stream north of Mutwai, but could find no seam *in situ*. He also gives the following analysis of a 4½-inch coal seam, only the top of which was visible, found on the right-bank of the Balia gorge :—

Mutwai (24° 5′ : 82° 45′).

	Per cent.
Volatile	25·0
Carbon	46·3
Ash	28·7
	100·0

This locality would appear to be about one mile W. S. W. of Onrawa (24° 9′ : 82° 44′) and is probably identical with outcrop No. 3 quoted from Sinor on page 457.

Mallet noted an outcrop of water-soaked coal about half-way down the waterfall at the head of one of the lateral gorges about a mile north-west of Murwani; and a similar outcrop in the next gorge to the west, where a 2½-foot seam was visible. He correlated the outcrops and noted both were covered by felspathic sandstones. It is obviously the same as Sinor's outcrop No. 2.

Murwani (24° 8′ : 82° 41′).

Mallet noted that the Naunagar seam, about 1½ miles north of Naunagar, was the thickest of which he had knowledge in the area. Mallet noted 23 feet of coal, the base of which was not visible[1] and states that the middle part of the seam was inferior, the best coal being near the base and top. His section of the coal and analyses of samples is as follows :--

Naunagar (24° 7′ : 82° 39′).

	Ft.	In.
" *a* Black carbonaceous shale	2	6
b Fair *coal* with one or two partings of carbonaceous shale . .	7	6
c Inferior *coal*	9	6
d Good *coal*	5	0
e Inferior *coal*	1	0
	25	6

[1] It will be seen on page 462 that I noted 18 feet of coal with three bands of shale.

Assays of b, c and d afforded

	b.	*c.*	*d.*
	Per cent.	Per cent.	Per cent
Volatile	28·8	25·1	27·0
Carbon	56·8	51·0	63·4
Ash	14·4	23·9	9·6
	100·0	100·0	100·0

The seam dips about N 10 E 5°. 50 or 40 ft. lower down, there are indications of another outcrop, unless we suppose it to be the same, which would make the bed 50 or 60 ft. thick.

There is another gorge, a few hundred yards to the eastwards, in which no trace of the coal, either in outcrop or fragment, is visible. It seems unlikely that such a thick seam should be quite obscured if it existed and I am therefore inclined to think that it is at least greatly reduced in thickness. A fault would of course explain the case, but there is no evidence of the existence of one."

These analyses may be compared with those given by Sinor (page 458) and myself (page 462).

Moher (24° 10′ : 82° 38′).

Mallet could not find *in situ* the outcrop of coal indicated by fragments found one mile south of Moher.

Parari (24° 12′ : 82° 35′).

He noted as follows regarding the coal 1½ miles south of Parari, referred to by Smith as Pudree—

" The Parari seam was also worked by Mr. Burke, but the quarry is now filled with water and not more than 18 ins. of the top of the bed is seen here and at the re-entrant angle of the stream close by. The late Mr. J. G. Medlicott, however, who was at the place when open, has described the seam in his MSS. report (p. 29). He states that the coal is very friable and unfit for transport, that it burns feebly and leaves a vast proportion of ash of a brick red color and contains much pyrites, that the band is 9 ft. thick of shale more or less carbonaceous in part, with layers of " lignite " and pure bituminous coal. An assay of one of the better layers near the top gave :—

	Per cent.
Volatile	31·8
Carbon	54·0
Ash	14·2
	100·0

In a gorge about a mile south of the last seam there is outcrop but only a foot at top is visible. It may be the same bed as the last."

This Parari seam is thus different from that given by Sinor as his outcrop No. 5, 1½ miles south of Parari [Purari (23° 57′ : 82° 30′)].

Mallet then gives a section with one foot of coal, becoming 10 inches 50 feet away, seen on both sides of a stream (Ballua *nala*) two miles north of Parwatwa Hill. He noted six inches of coal in the Tipkapani *nala*, $1\frac{1}{2}$ miles N. N. E. of Parwatwa Hill, which joins the Ballua from the south. The coal thins rapidly to two inches.

Parwatwa Hill (24° 2′ : 82° 30′).

All the preceding outcrops of coal occur on sheet 8 of the old Rewa Topographical Survey (186 U. P. or 73 L/12 and 16). The following outcrops were noted by Mallet on sheet 18 of the Rewa Topographical Survey (U. P. 187 and 64 I/9 and 13) :—

Outcrops of coal on sheet 18.

Mallet noted 2 feet 8 inches of coal near the head of the glen south of Dheka Hill in the bed of the stream, and a few yards lower down, one foot with grey shale under it. He states if the coal in the two places belongs, as it seems to do, to one seam, it must have a minimum thickness of about seven feet. This is obviously the same seam as Sinor's outcrop No. 5 ($2\frac{1}{2}$ miles south-west of Koelkut and $1\frac{1}{2}$ miles south of Purari (23° 57′ : 82° 30′)). The village of Dheka lies $2\frac{1}{2}$ miles to the south-east of Purari.

Dheka (23° 55′ : 82° 32′).

Mallet mentions lumps of coal strewn in the bed of the stream near its mouth which joins the Mear on the south side, one mile above Muri, but no outcrop was visible.

Muri (23° 52′ : 82° 34′).

Amount of coal.

Mallet's conclusions regarding the amount of coal in this area are of interest :—

"Thus it will be seen that the number of outcrops is not large. No doubt seams exist which are entirely concealed by talus and debris, nearly all the known ones being visible only where cut through by some stream ; but still the number of outcrops, as compared with their frequency in other fields, forms some index to the total amount. There is also reason to suppose that the seams here, as elsewhere in the Barakurs, do not extend over large areas, sometimes thinning out entirely within short distance. Taking, therefore, the two facts of the comparatively small number of seams and the small area which they individually probably occupy, this portion of the Singrowlee field certainly cannot be considered *rich* in coal, although no doubt there are some very fair seams."

Mallet concludes his report with an account of the trappean dykes and sheets which he notes are very abundant among the sandstones on sheet 18. South of Danhara (23° 53′: 82° 35′), there is a vertical dyke cutting through Talchirs which is 60 or 70 feet thick. He could find no difference

Burnt seams.

lithologically between the vertical dykes and the horizontal sheets In certain cases, these have affected the coal of the area because in a footnote to his report dated September, 1876, Mallet states that one specimen he had difficulty in identifying was, he concluded, merely slag produced by burning coal seams.

Summary of Mallet's report.

A thorough study of the foregoing observations shows the importance of Mallet's long-forgotten report in view of the attention which has lately been directed to the possible development of the coal near Kota. Certain parts of the Mirzapur district are actually described by him, but the bulk of his report is occupied by descriptions of the contiguous areas of Rewa State to the west and south and the extreme northern part of Surguja State. As his work was more detailed than any previous or later observer, his general description of the area and his remarks on the constituent series and stages of the Gondwana system, as developed here, have particular importance. One may reiterate his conclusion that the seams developed are relatively few; and that though thick seams, especially at Naunagar, are occasionally developed, there is every reason to believe that these thin very rapidly. The continuity of each seam would have to be proved by pits or boring before it would be safe to formulate conclusions regarding the reserves of coal available.

R. D. Oldham, 1895.

Amongst other areas, the Kota region was examined by R. D. Oldham in 1894 and 1895. Thus it is stated in *Rec. Geol. Surv. Ind.*, XXVIII, Pt. 3, p. 117, (1895), that Mr. Oldham found two coal-seams of six feet and 5 feet 6 inches thicknesses; the former was 1½ miles S. W. by W. of Ujaini [Ujehni (24° 10′ : 82° 25′)], and the latter two miles north of Amlia (24° 2′ : 82° 28′), both being near the eastern edge of standard sheet 476. In *Mem. Geol. Surv. Ind.*, XXXI, Pt. 1, p. 133, (1901), by R. D. Oldham, P. N. Datta and E. Vredenburg, Oldham states :—

"I have seen this junction" (Gondwanas and Crystallines) "at two places only. North of Ujaini (a short way off the map) the bottom bed of the Damudas was a breccia of quartz and felspar, evidently the *debris* of a pegmatite of quartz and pink felspar which is intrusive in the crystallines close to the boundary. The other place was near Bichiadol, where the sandstones are found turned up to a dip of 70 to south by east and are considerably indurated. It seems that the boundary is faulted to near the Mohan and eastwards of that natural."

V. Ball and R. R. Simpson in their memoir on the Coalfields of India [*Mem. Geol. Surv. Ind.*, XLI, Pt. 1, pp. 79-80, (1901)] do not add anything much to the knowledge gained by the reports of Wroughton, Smith and Oldham. They reiterate that the analyses of samples brought to Calcutta appear to have been disappointing; they state that 1,000 tons of coal was raised in the Mirzapur district in 1896, but the enterprise was soon abandoned.

V. Ball and R. R. Simpson, 1901.

K. P. Sinor examined the coal outcrops at Kota and in the adjoining portion of Rewa State and the following is an extract from his report published as *Bull. Geol. Dept., Rewa State*, Calcutta, 2, pp. 54-56, (1923) :—

K. P. Sinor, 1923.

"Captain Wroughton was the first to discover coal near Kota in 1840. Trial pits put down near this place disclosed seams of coal aggregating to about 5 feet in thickness. It is stated that during the forties and fifties of the 19th century coal was mined near Kota and Parari in Singrauli and was carried to Mirzapur over very bad roads for a distance of about 80 miles. The coal was sold for use on the Ganges steamers. From reports made on this coalfield by W. Roberts in 1855 and by D. Smith in 1857 it appears that the outcrop of coal near Ghuraoli, two miles to the north of Naunagar, was discovered at that time, as also the outcrops to the S. W. of Koelkut and Raondi between Parari and Kachra. The first outcrop is stated to occur at Toorah but in the large trigonometrical survey maps (scale 1 inch=1 mile) no such village is marked. The writer of these notes found this outcrop two miles north of Naunagar in the hill range (composed mostly of Barakar rocks) which runs for nearly 15 miles in an east to west direction. The thickness of the coal at the outcrop was found to be 8 feet. About a hundred yards to the north of the outcrop an old pit having a diameter of about 7 feet was seen. The pit which seemed to be more than 50 feet deep is in a good state of preservation. It was evidently sunk for one of two reasons—either for trial purpose or for taking out coal from some of the lower seams. None of the local men could give definite information on this point.

Previous observers.

The important outcrops of coal hitherto found occur chiefly in the eastern part of the coalfield. The following shows the exact locality of the various outcrops which occur in this field :—

Outcrops of coal.

(1) About 2 miles due north of Naunagar, in the Ghuraoli Hills (24° 8′ : 82° 39′).
(2) About a mile to the east of the Trigonometrical Station of Ghuraoli.
(3) Near the boundary line between Rewa State and Mirzapur and about a mile to the S. W. of Onrawa (24° 9′ : 82° 42′).
(4) Three miles to the N. E. of Tulda and about 1½ miles to the S. W. of Thurwa (24° 11′ : 82° 35′).
(5) 2¼ miles S. W. of Koelkut and 1½ miles south of Parari (23° 55′ : 82° 30′ 30″).
(6) ¾th of a mile west of Kachra (23° 52′ : 82° 31′ 30″).

(7) $2\frac{1}{2}$ miles due west of Chitouli (23° 53′ 30″ : 82° 32′).
(8) In the stream near Amlei (24° 2′ : 82° 29′).
(9) In the Bandha Nadi about half a mile to the south of Ujehni (24° 10′ : 82° 25′).
(10) In a feeder of the Mohan River close to Ubri (24° 9′ : 82° 20′) [mostly carbonaceous shale].

The outcrops near Naunagar, Koelkut, Amlei and Ujehni are important. The outcrop in Ghuraoli Hills north of Naunagar consists of a seam of coal about 8 feet thick. The seam near Koelkut and Parari (otherwise known as Pudri) measures about 6 feet in thickness while the Amlei and Ujehni seams measure $5\frac{1}{2}$ and 6 feet respectively.

After the discovery of coal near Kota in 1840 by Captain Wroughton it appears that the coal seams near that place were worked for some time but it is not definitely known for how many years these mines were worked. According to D. Smith coal was being quarried at Pudri (Parari) in 1857 the thickness of the seam being 21 feet. The last attempt at mining coal in Mirzapur district was made in 1896, when about 1,000 tons of coal was produced.

The average composition of two specimens of Kota coal obtained by Wroughton was as follows :—

Volatile matter	43·35
Fixed carbon	54·65
Ash	2·00

The results of anlyses of Singrauli coal found by R. D. Oldham of the Geological Survey of India were stated to be disappointing and to have given poor results.

In the opinion of the writer it is extremely likely that the two specimens of coal obtained by Captain Wroughton which gave a remarkably low percentage of ash (2 per cent.) were specially selected, whereas the specimens collected by Oldham probably consisted of weathered specimens mixed with carbonaceous shale. The following are results of analyses of carefully sampled specimens of Parari and Naunagar coal :—

	Parari Coal (near Koelkut).	Naunagar Coal.
Moisture	5·68	6·28
Volatile matter	28·14	26·62
Fixed carbon	52·72	49·42
Ash	13·46	17·68."

I have given Sinor's notes in full as they are important. He mentions Parari [Purari (23° 57′ : 82° 30′)], otherwise known as Pudri. This village is 19 miles south-west of Kota and is hardly likely to be the Pudree mentioned by Smith as 18 miles west of that place. Smith's Pudree is definitely the Parari (24° 12′ : 82° 35′) with which Mallet and I have correlated it. However, coal does occur at Purari as we have seen from Mallet's progress report.

In his Preface, Sinor expresses the view that it seems likely that the Singrauli coalfield will come into prominence in the near future as there was serious talk of the construction of a railway line connecting the East Indian Railway near Sone East Bank with the Bilaspur-Katni Branch line of the Bengal Nagpur Railway. I deal more fully with this matter below. He points out that the quality of coal generally met with in Rewa State has a calorific value of about 5,500 calories; whilst the best varieties of Bengal coal have a calorific value of about 13,000 B. T. Us., which is equivalent to about 7,220 calories. Most Rewa coal is thus a good second-class coal.

Second-class coal.

I was the last geologist to visit the outcrops of coal in that part of the Singrauli coalfield adjoining the Mirzapur district, my work being in connection with the Central Indian Coalfields Railway Reconnaissance Survey. Two alternative alignments were suggested for this railway, Line A, from Anuppur, on the Bilaspur-Katni branch line, to Hutar; and the other, Line B, from Katni to Hutar but with two alternative alignments one through the north part of the Singrauli coalfield and the other through the southern part of the same field. Line A had decided advantages, but the construction of a broad-gauge railway along this alignment is far from completion and seems held up indefinitely. The Geological Report, containing my observations in great detail, was published by the Central Indian Coalfields Railway Survey at Ranchi. In all I covered 1,200 miles from December, 1922, to April, 1923; my examination of the Singrauli coalfield was made in January, 1923, and was, of necessity, limited by the time at my disposal.

A. L. Coulson, 1923.

I give below certain extracts from my report. In explanation thereof, I would add that the analyses of samples collected by me in the field were completed by Mr. Mahadeo Ram in the laboratory of the Geological Survey of India. I determined the calorific values myself by means of a Berthelot bomb calorimeter, being indebted to my former colleague, Dr. W. A. K. Christie, for assistance in the manipulation of the apparatus. The calorific value as determined by the bomb calorimeter is somewhat higher than the calorific value of the same fuel when burned under a boiler; in the first case the water in the fuel and that formed by the oxidation of the hydrogen is condensed to water, giving out heat; whereas in the latter case the steam is not condensed. It will be noted

that the calculated and the experimentally determined calorific values have been given for the analyses of my samples. The calculated values were obtained by means of Goutal's formula as modified by A. J. Cox.[1]

"The next seams examined were in the neighbourhood of Ujehni. Sinor[2] mentions the occurrence of two seams, 5½′ and 6′ respectively in the Bandha N., ½ m. south of Ujehni. Oldham[3] found a seam 6′ thick 1½ miles south-west by west of Ujehni. I noted the following section in a small stream about 1 mile east of Ujehni, the bearing of Jacobat hill being N. 30°E. :—

Ujehni (24°10′ : 82° 25′).

1. Micaceous sandstone.
2. Coal (No. 23) . . . . about 3″
3. Shaly micaceous sandstone.
4. Shales.
5. Micaceous sandstone.
6. Shales.
7. Coal (No. 24) . . . . about 6′ to 8′
8. Micaceous sandstone.

Dip.—12° N. N. W.

The section is an extremely poor one and it was impossible to measure the thicknesses of the seams. The samples obtained are rough but may be considered to indicate the nature of the seams as these did not vary much in quality :—

	No. 23.	No. 24.
Volatile matter	22·89	29·05
Fixed carbon	26·96	33·50
Ash	43·40	30·60
Moisture	6·75	6·85
	100·00	100·00
Calorific power—		
Theoretical	3630	4534
Experimental	3503	4539
Character of coke	N. C.	N. C.
Colour of ash	White	White

An examination of these analyses shows that the coals are of no value commercially.

I went from Ujehni to Banda about 7 miles to the south, as I had heard that coal was known there but could find no traces of coal in the stream there. Also, the villagers did not appear to know of the existence of any seam though their ignorance might be ascribed to the fact that a tiger had been killed on the outskirts of the village.

Banda (24° 5′ : 82° 25′).

[1] *Philipp. Journ. Sci.*, IV, (May, 1909); see also F. C. Hughes, *Trans. Min. Geol. Inst. Ind.*, V, pp. 114-161, (1910).
[2] *Bull. Geol. Dept., Rewa State*, 2, p. 55, (1923).
[3] *Rec. Geol. Surv. Ind.*, XXVIII, p. 117, (1895).

Manhari (24° 10′ : 82° 29′). In a stream about $2\frac{1}{2}$ miles E. S. E. of Ujehni and about 1 mile S. W. of Manhari the following section was noted :—

1. Sandstone	8′	
2. Shales	2′	0″
3. Sandstone	1′	6″
4. Shales	10′	0″
5. Carbonaceous shales	1′	11″
6. Coal		6″
7. Carbonaceous shales		4″
8. Coal (No. 27)	1′	0″
9. Ferruginous sandstone		6″
10. Shales	1′	6″
11. Coal, banded	1′	3″
12. Shales	2′	0″
13. Coal, shaly	1′	9″
14. Coal	1′	0″
15. Shales	4′	4″
16. Sandstone	3′	6″
17. Hard sandstone		4″
18. Carbonaceous shales	3′	0″
19. Coal, under water	3′	6″
20. Micaceous sandstone.		

Dip.—$13\frac{1}{2}$° N. W.

There is thus 9′ 0″ of coal in 6 seams 6″, 1′ 0″, 1′ 3″, 1′ 9″, 1′ 0″ and 3′ 6″ thick in 24′ 6″ of strata. Of these seams bed number 8 (No. 27) was sampled as follows :—

Volatile matter	23·48
Fixed carbon	36·86
Ash	24·14
Moisture	15·52
	100·00

Calorific power—

Theoretical	4669
Experimental	4033

Does not cake.

Ash : Greyish-white.

It appears that beds 13 to 20 inches inclusive of the above section may be correlated with beds 2 to 8 inclusive of the Ujehni outcrop. This would necessitate a fault between the two exposures.

A short distance below this outcrop, another seam 2′ to 3′ thick was noted but it was partly under water.

The stream to the west of Pouri was followed for 2 to 3 miles but no traces of coal were found."

Naunagar (24° 7′ 82° 39′).

I then refer to D. Smith's reported discovery of coal at Toorah near Naunagar and also to Sinor's 8-foot seam of coal, two miles north of Naunagar, which is evidently the same seam. I also quote Sinor's analysis of his sample given on page 27 of this paper and add :—

"About 1½ to 2 miles north of Naunagar, 18′ of coal were noted cropping out under a hard sandstone and dipping 2° 30′ N. E. The indications are that it is of greater thickness. In this 18′ seam, there were three bands of shale but the total thickness of these was not greater than 1′. The coal is composed of alternate layers of bright and dull coal and its average quality appeared to be above that of the Singrauli coals already described. Two samples were taken, one (No. 31) about 11′ from the top of the seam, and the other (No. 32) about 8′ from the top :—

	No. 31.	No. 32.	Average of the 3 samples.
Volatile matter	28·51	30·17	28·43
Fixed carbon	39·06	42·72	43·73
Ash	20·43	11·74	16·62
Moisture	12·00	15·37	11·22
	100·00	100·00	100·00
Calorific power—			
Theoretical	5156	5615	5405
Experimental	4995	5636	..
Character of coke	N. C.	N. C.	N. C.
Colour of ash	White	White	..

The average of the three analyses places it as a second to third class coal but it appears to be in abundance. The high moisture content is not to be wondered at as the seam crops out in the bed of a stream.

According to the guides, this seam was worked twice previously, once 60 years ago and the second time 20 years later, by the same people who mined the coal at Kota (U. P.). The coal was carried to Mirzapur. This is the most promising seam in the Singrauli field. As it occurs towards the head of a very steep valley, it is not very conveniently situated for working but it should be possible to convey it to the foot of the hills to where a railway siding could be constructed."

Kota (24° 6′ : 82° 25′).

I then refer to Captain Wroughton's analysis of coal fragments from Kota and note :—

"Whilst I was at Kota, I inspected the old shafts and tunnels but could gain no information owing to their extreme state of disrepair. Practically no coal could be seen *in situ* though abundant fragments could be found in the dump heaps. A certain Mr. Walsh and his family were chiefly responsible for the working of the mine but they one by one died through malaria and other causes and nothing further was done. I was shown so-called 'coal' in a stream to the west of the main

workings but it was only carbonaceous shales. In the same stream about 100 yards south-west of an old air shaft, I found the following:—

1. Soil.		
2. Hard felspathic sandstone	6′	0″
3. Coal, very decomposed		4″
4. Muddy shales	1′	6″
5. Sandstone.		

Dip.—2° 30′ N. E. (the same as at Naunagar).

I almost encircled the hills to the north-west of Kota at various levels but could find no traces of coal. It is a doubtful question if the coal now remaining at Kota would justify the expense of reopening the mine.

Sohira (25° 3′ : 82° 28′). In a stream $1\frac{3}{4}$ miles east-north-east of Sohira, the following section was noted:—

1. Sandstone.		
2. Shale	4′	0″
3. Coal, bright, banded		$8\frac{1}{2}$″
4. Mudstones.		

Dip.—18° 10′ S. W.

In another tributary of the same stream, $2\frac{1}{2}$ miles east-south-east of Sohira I found:—

1. Soil.		
2. Hard massive sandstone	25′	
3. Soft shale		4″
4. Harder shale		6″
5. Coal, banded		4″
6. Soft muddy shales		3″
7. Mudstones	4′	6″
8. Hard sandstones.		

The beds were practically horizontal but had a slight general dip to the north. The same seam lower down this stream diminished in thickness to about 1″. It is probable that coal occurs in a small stream rising near Chitroe.

Amlia (24° 2′ : 82° 28′). Sinor mentions important coal as occurring near Amlia, 6″ in thickness. The following section was noted 3 miles west-north-west of Amlia in the Amlia Ghat:—

1. Hard sandstone.		
2. Carbonaceous shale	1′	2″
3. Coal, poor		7″
4. Carbonaceous	1′	4″
5. Coal (No. 29)	3′	0″ (exposed).
6. Water.		

Dip.—2° W. N. W.

The bottom of the seam was not exposed but I have no doubt that this is the same seam as Sinor's. Like most of the seams exposed, it was impossible to take

a good sample but the following analysis indicates the nature of the top part of the seam :—

Volatile matter	26·35
Fixed carbon	41·10
Ash	25·18
Moisture	7·37
	100·00

Calorific power—	
Theoretical	5333
Experimental	5137

Does not cake.
Ash : Light buff.

Like the Naunagar seam, it is situated at the head of a steep valley and so not well situated for working. Also the quality is poor as can be seen from the analysis above."

Summary of results.

Summarising the results of my survey, it would seem that the Ujehni coals are of no value commercially. The Manhari coal to the E. S. E. of Ujehni is also worthless. The thick seam of coal at Naunagar is a second to third-class coal, occurring in abundance. The Amlia coal, like the Naunagar coal, is not well situated for working and is of poor quality. On account of the flooded state of the old pit, the Kota coal in the Mirzapur district of the United Provinces could not be examined; but I could find no traces of workable coal in the hills nearby and concluded that it was very doubtful if the coal remaining would justify the expense of reopening the mine.

J. A. Dunn, 1929.

Dr. J. A. Dunn visited the corundum deposits at Pipra (23° 58′ : 82° 44′) in Rewa State in the field season 1926-27 and the results of his work are given on pages 188-203 of *Mem. Geol. Surv. Ind.*, LII, Pt. 2, (1929). He did not examine the nearby coal deposits with which we are concerned at the present.

C. S. Fox, 1934.

In his comprehensive account of "The Lower Gondwana Coalfields of India", Dr. C. S. Fox [*Mem. Geol. Surv. Ind.*, LIX, pp. 179-182, (1934)] gives references to the previous published literature which I have quoted in this paper and publishes the analyses given by, or quoted by, me in my Geological Report. He concludes that the Parari (really Purari) six-foot seam analysed by Sinor is fairly attractive and the

Naunagar 18-foot seam examined by me, if sampled foot by foot, may yield a good quality coal. He adds (page 182):—

Reserves of coal.

"It is certain that the Singrauli coalfield must contain a large quantity of coal, but the evidence so far does not show that the quantities of good coal are large. The coalfield is at present so inaccessible that it has not justified expensive exploration by extensive boring. However, the six-foot Parari seam and the 18-foot seam near Naunagar cannot be dismissed without some word in regard to reserves. If the six-foot seam mentioned by Sinor can be followed, the amount of coal per square mile is 6,000,000 tons in this unit of area; and the 18-foot seam found by Coulson, if considered only 15 feet thick, will average 15,000,000 tons per square mile. Should the Central Indian Coalfields Railway be constructed on the B alignment modified to pass close to Naunagar and Amlia, both these seams will be within easy reach of feeder lines. At present the building of the through line from Daltonganj westwards is in abeyance, and the condition of the coal industry does not permit of any hope of the opening up of new coalfields of coal of the quality so far found in the Singrauli field."

III. CONCLUSIONS.

Geological maps of the area.

The foregoing section gives a comprehensive account of the present state of knowledge regarding the coal known to exist near Kota in the Mirzapur district of the United Provinces and in the adjoining parts of the Singrauli coalfield in Rewa State. Admittedly our knowledge of the area is far from complete, especially of that part of the Mirzapur district. The only geological maps, which have not previously been published, are on the scale of 1 inch = 1 mile and 1 inch = 4 miles. The former is Mallet's original map of sheet 8 of the Rewa Topographical Survey and the latter is the result of Oldham's party continuing the work originally begun by Mallet. A sketch geological map of the area between latitudes 23° 50′ and 24° 15′ and longitudes 82° 15′ : 83° 0′, taken from the above unpublished map of Oldham's party forms Plate 22 of this report. It is less detailed than Mallet's map of sheet 8 of the Rewa Topographical Survey; but as Mallet's map of the complementary sheet 18 of the survey is not available, it has been considered advisable to use Oldham's map for publication. It will be seen from the map that the area of Barakars within the limits of Mirzapur district is very small.

Extensive exploration not at present justified.

No good deposits of coal of first-class quality are known to exist in the area under discussion; nor does there appear to be much likelihood of such being found. On the contrary, judging by the known quality of the best seams in the Singrauli coalfield in the Rewa State adjoining the Kota area, it would seem vain to hope for any coal better than second-class quality. Whilst Dr. Fox has stated that the Purari seam is very attractive and that the Naunagar seam, if sampled foot by foot, may yield good quality coal, the analyses so far available do not lend much encouragement for hopes for large extraction from this region of coal that would be able to compete with Bengal and Bihar coal. When, if ever, the railway line is completed, then an added fillip may be given to the search for coal in this area. Again, modern developments in the utilisation of poor-quality coal, on the lines sketched by various authors in papers read at the recent Symposium on Coal in India, held in Calcutta on the 25th and 26th August, 1939, under auspices of the National Institute of Sciences of India, may, in the course of time, hold out hopes for greater importance for the Singrauli (and Kota) coal. Meanwhile, however, the known quality of the seams does not seem to justify the extensive exploration in boring which must be undertaken before the area can be considered to have economic importance. Under these circumstances, happy flights of imagination about cheap power to be generated from the Kota coal are, to say the least, very premature.

IV. LIST OF PLATES.

PLATE 22.—Geological sketch map of part of the Mirzapur district of the United Provinces and of the adjoining areas of Rewa State, Central India, Surguja State, Eastern States (after R. D. Oldham). Scale 1 inch =4 miles. The area included in the map lies between latitudes 23° 50′ and 24° 15′ and longitudes 82° 15′ and 83° 0′, being comprised of parts of the following one-inch Standard sheets:—476 C. I. and Raj. (9 Rewah; 63 L/4 and 8); 477 C. I. and Raj. (19 Rewah; 64 I/1 and 5); 186 U. P. (8 Rewah; 63 L/12 and 16); and 187 U. P. (18 Rewah; 64 I/9 and 13).

MANGANESE NEAR CHAIBASA, SINGHBHUM. BY J. A. DUNN, D.Sc., D.I.C., F.N.I., F.G.S., *Superintending Geologist, Geological Survey of India.* (With Text Figure 1.)

INTRODUCTION.

In his monumental work on the manganese deposits of India, published in 1909, Fermor gave an account of certain small deposits which occur near Chaibasa, at intervals up to as far south as six miles from the town.[1] At that time the small amount of mining which had been done had not provided well defined sections of the rocks but still, Fermor's detailed description has proved largely accurate. Since then, further mining has exposed clearer sections, and, during a recent resurvey of the locality, certain additional relations of the rocks became noticeable which suggest an extension of Fermor's view on the origin of these deposits.

Fermor described the manganese deposits as being of two types: irregular surface deposits of lateritic aspect, and bed-like layers of manganese-ore from one to six inches thick interbedded with rocks of sedimentary origin. The manganese minerals are psilomelane and pyrolusite, the surface ores being limonitic.

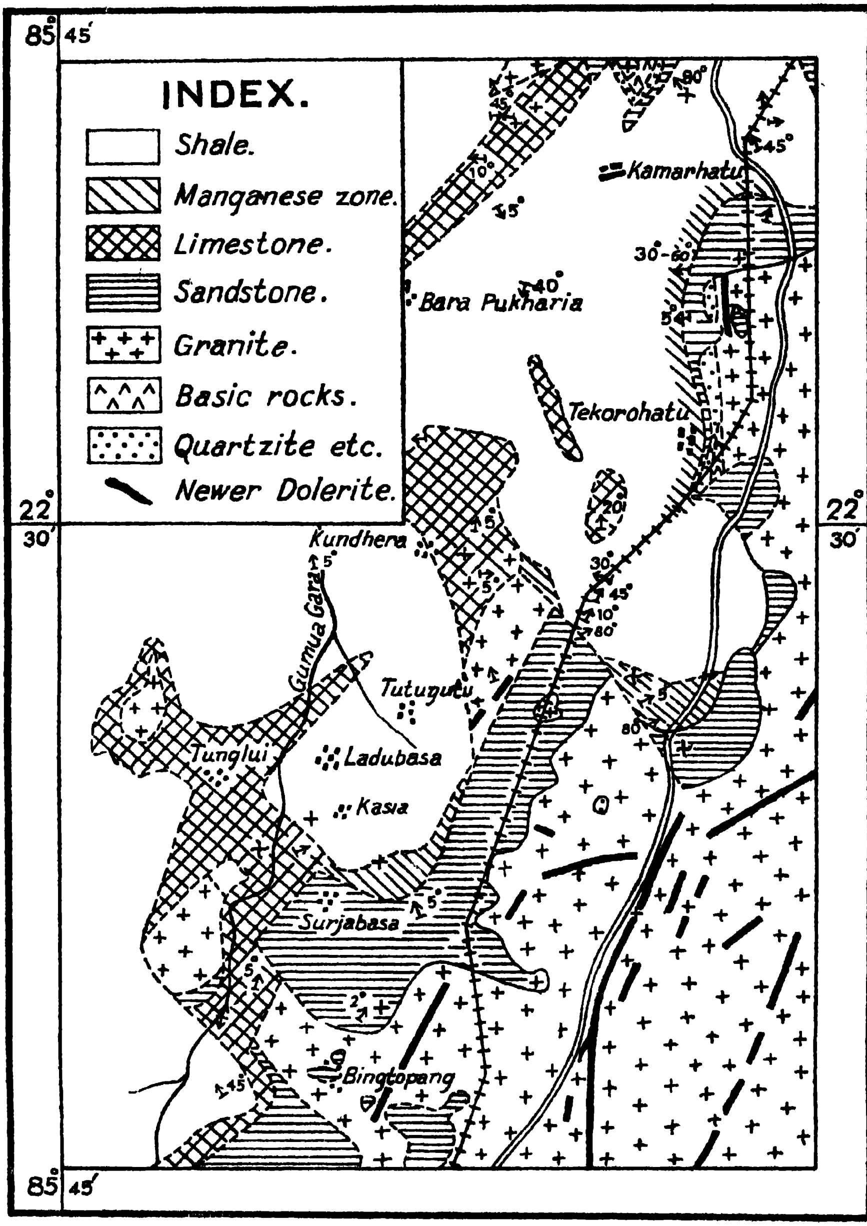
The associated rocks were described by Fermor as consisting of "unctuous clay slates and sericite phyllites; purplish sandstones, quartzites, and grits which are often of the nature of greywackes; together with red and pink jaspers and jaspery quartzites".

The sandstones and grits are the bottom bed of the group and rest on the underlying granite.

Fermor suggested that "these manganese and iron-ores have been formed by the percolation of solutions containing manganese and iron which have replaced indiscriminately whatever rock was at the surface". He believed that the solutions derived their manganese content from an unknown adjacent rock, probably of the nature of hematite-schist.

To Fermor's conclusions I would now add (*a*) that much of the replaced rock was a shaly limestone from which all the calcareous material has been removed, and (*b*) that the original source of the

[1] L. L. Fermor. The manganese deposits of India, *Mem. Geol. Surv. India*, XXXVII, pt. 4, pp. 618—639, (1909).



Map of the manganese area, south of Chaibasa. Scale, 1 inch = 1 mile.

manganese was an underlying gonditic garnet-quartz-rock, or other manganese bearing rock of the Iron-ore Series.

GEOLOGY.

Until recently, the sedimentary rocks to the south of Chaibasa, in which the manganese deposits occur, were grouped with the Iron-ore Series, and the Singhbhum granite was thought to be intrusive into them. Recently, however, it has been found that these rocks are part of a younger group known as the Kolhan Series which rests unconformably not only on the Iron-ore Series but also on the Singhbhum granite.[1]

Iron-ore Series.

The Iron-ore Series elsewhere in Singhbhum consists of phyllites, mica-schists, quartzites, quartz-schists, banded jaspery quartzites, cherts, dolomitic limestones, lavas, and basic igneous intrusives with their derived schists. Beneath the base of the Kolhan Series south of Chaibasa, the only representatives of the Iron-ore Series are inclusions in the granite of metamorphosed basic igneous rocks, jasper and quartz-schists.

Garnet-quartz-schist.—Close to the edge of the Kolhan Series, in the railway cutting to the east of Tekorohatu, there is a massive mottled jasper associated with talc-schist. This jasper, further north, grades to a quartz-schist, and a thin-section of this showed that it is of fine quartz with occasional streaks of fine pale yellow to colourless garnet, and some sericite. The outline of some of the fine quartz suggests that originally rhombohedra of a carbonate were present. The rock is similar to some of the normal gondites but the low MnO content of the rock (0·30 per cent.) indicates that the garnet does not contain more than 5 per cent. MnO. Although this is the only outcrop recorded in Singhbhum, it is possible that others may occur below the Kolhan beds in this vicinity. The nearest gonditic rocks occur in Gangpur, where they are associated with dolomitic limestone. It is of interest to record that a dolomitic limestone occurs in the Iron-ore Series to the north of Chaibasa and that dolomitic limestones have been found associated with the manganese deposits in the Iron-ore Series to the south of Jamda in Keonjhar State, where, however, the associated cherts and phyllites have not suffered a high degree of metamorphism.

[1] J. A. Dunn, *Mem. Geol. Surv. India*, LXIII (3), (1940).

Kolhan Series.

The sequence within the Kolhan Series is as follows :—

3. Shales.
2. Limestones.
1. Sandstones.

The outcrop of the basal sandstone strikes S. S. W. from Chaibasa, and is either horizontal or dips gently westward. The overlying limestones and shales are frequently horizontal or gently rolling, but they have been considerably disturbed in places, particularly along fault zones. In this vicinity the Kolhan rocks are swarming with quartz veins, sometimes slightly manganiferous, and much of the shale has been replaced by a cavernous quartz which partly retains the bedding structure. Such quartz replacement is more particularly prevalent in the fault or highly disturbed zones. Although elsewhere the aspect of the Kolhan shales is that of a relatively unaltered shale, here, in this locality to the south of Chaibasa, wherever they are closely riddled by quartz veins they have a typical phyllitic sheen. It is obvious that these rocks have been thoroughly permeated by hot solutions.

Sandstone.—The basal sandstone varies in thickness. In places, near Chaibasa, it is at least thirty feet thick, but at times it appears to thin out almost completely. For example, to the east and west of the inlier of granite north of Indkuri (22° 28′, 85° 46′) only limestone is found to crop out, except at the south-east corner where conglomerate occurs; however, as the country is much covered with alluvium the boundaries of this inlier may be faulted. The granite basement below the sandstone appears to be rather uneven and small inliers of granite are sometimes exposed.

Limestone.—The limestone attains a thickness of at least thirty feet at Kundbera (22° 30′, 85° 47′), but it is known to be lenticular and several miles to the south it thins out completely in places. It directly overlies the basal sandstone, and, south of latitude 22° 28′, outcrops of the two rocks strike parallel in close juxtaposition for many miles. North of latitude 22° 28′, however, there is an unusual change in the relation between the outcrops of the two rocks. In consequence of rolling dips, inliers of the limestone crop out within the shales at Kundbera and Bara Pukharia, some distance from the border of the basal sandstone, whilst against the outcrops of basal sandstone, and coinciding with the location of

the manganese deposits, no limestones are found. It might be presumed that this absence of limestone along the outcrops of sandstone north of latitude 22° 28′ is in consequence of its lenticular character, but it will be suggested later that the same solutions which gave rise to the interbedded lenticles of manganese leached away also the calcareous content of the limestone.

The limestone is usually pink in colour, but grey and greenish varieties are common. It sometimes contains thin lenticles* of chert of the same colour, whilst laminae of phyllitic shale are extremely abundant. Chlorite, sericite and quartz are usually abundant, and the rock has a typical phyllitic sheen on the bedding parting. Ripple markings have been observed on the bedding surface, and the rock is presumably of shallow water origin.

Throughout the whole extent of its many miles of outcrop this limestone is remarkably consistent in its character and appearance, the only variation being in colour. The following analysis of a typical specimen indicates the high proportion of impurities present :—

Spec. No.	54/504
Locality	South of Basakuti.
SiO_2	22·10
Al_2O_3	8·51
Fe_2O_3	0·39
CaO	35·80
MgO	0·72
Na_2O	1·34
K_2O	0·32
MnO	0·84
Loss on ignition	30·13
TOTAL	100·15
Specific Gravity	2·75

Analyst—R. Dutta Roy.

Under the microscope the quartz grains in the limestone are usually fine and angular. The chlorite is deep green and sometimes quite well developed in flakes, as also is the sericite. The associated lenticles of chert, usually pink in colour, contain innumerable rhombohedra of calcite.

The manganese country rock.—It will be noticed from the map that all of the manganese occurrences are located in positions where the limestone would have been expected to occur had it maintained the normal position which it occupies to the south, that is, adjacent

to and immediately overlying the sandstone. Many quarries have been excavated on these manganese deposits in recent years and every one of them, without exception, exposes a peculiar, friable, porous and almost incoherent bedded sericite-biotite-quartz-" schist" containing thin interbedded lenticles of pink chert up to two inches thick, and also of manganese-ore. This "schist" is usually more or less horizontal or gently undulating, a maximum dip of 30 degrees west being found half a mile north of Tekorohatu, and a very local dip of 80 degrees along a fault at Kelendeh (22° 29′, 85° 48′).

Under the microscope, the biotite in the "schist" is seen to be a deep brown variety; it presumably represents the chlorite in the original limestone. The fine angular quartz grains are similar to those in the limestone, as also is the sericite.

The chert lenticles are found, under the microscope, to contain numerous rhombohedra, originally carbonate crystals but now either leached out or occupied by fine chert or by manganese-ore.

ORIGIN OF THE SERICITE-BIOTITE-QUARTZ-" SCHIST".

The position of the "schist" with respect to the basal sandstone, the similarity of its contained chert lenticles with those in the limestone, and the identity of the sericite and quartz in the schist with the insoluble portion of the limestone, all point to the complete leaching of the calcareous material from limestone which originally overlay the purple sandstone along the line of manganese deposits south of Chaibasa.

Closely examining an outcrop of the limestone south-east of Kundbera, where the bedding is horizontal, I noticed small patches in which the lime had been completely removed leaving a soft almost incoherent sericite-quartz which was identical in appearance with beds of the "schist" which lie horizontally in a prospecting pit for manganese 200 yards to the east—the intervening ground is soil covered. A similar alteration was also noticed in the limestone to the west of Kasia.

Occasionally, the basal sandstone also contains manganese lenticles, as also do the overlying phyllitic shales. Sometimes, the sandstone has been leached leaving a sericitic material similar to the "schist" but more sandy. Some of the quarries have cut through the sandstone to the talc-schists below. The surface

lateritic occurrences were originally found on any of these rocks, but more particularly on the sandstone which is quite frequently slightly manganiferous.

SOURCE OF THE MANGANESE.

The source of the manganese is of interest. The outcrop of gonditic manganiferous garnet-quartz-rock to the east of Tekorohatu has been already described, and it is quite probable that similar manganiferous rocks may occur below the Kolhan beds. The denudation of these manganiferous beds in Kolhan times could, of course, have provided detrital manganiferous material in the basal Kolhan sediments. It is not at all improbable that some of the manganese in the basal sandstone was of such detrital origin, but the evidence of leaching of the calcareous material from the limestone and the low manganese content of the unleached limestone indicate that the manganese lenticles in the "schist" have been deposited by solutions. These solutions could have derived their manganese content from the manganiferous rocks which underlie the Kolhan sandstone, and in addition, perhaps, from the limestones and sandstones themselves.

The nature of the solutions is obscure. They are, of course, not related to the Singhbhum granite as the Kolhan Series is much later. There have been some unusual fault movements in the Kolhan Series in this vicinity, and hot waters have presumably found these fault zones to be easy channels of circulation, spreading out also into the neighbouring horizontal rocks.

NON-MARINE LAMELLIBRANCHS, ETC., FROM THE 'SPECKLED SANDSTONE' FORMATION (PUNJABIAN) OF THE SALT RANGE. BY F. R. COWPER REED, Sc.D., F.G.S. (With Plate 23 and Text Figures 1 to 9.)

INTRODUCTION.

A collection of numerous small lamellibranchs in the state of casts and impressions with a few fish-scales and ostracods were found in 1932 by Mr. E. R. Gee associated with Lower Gondwana plants (*Glossopteris*, *Gangamopteris*, etc.), in black carbonaceous shales about 25 feet above the Talchir Boulder-bed, that is, near the base of the 'Speckled Sandstone' Series* (Punjabian) at the stream-junction just north-east of Pt. 1850, 2 miles S. S. E. of Kathwai Rest-house (32° 29′ 15″: 72° 11′ 45″), District Shahpur, Punjab (Sheet 43D/3). The lamellibranchs are very abundant, but mostly in a poor or fragmentary condition, though a few specimens show the hinge-line and traces of the dentition.

The determination of the species and even of the genus of such lamellibranchs is uncertain in many cases, so that only a comparison with established species can often be made. There are however, some definitely new species, the affinities of which are discussed below.

The fish-scales appear to belong to the genus *Elonichthys*, but they occur isolated and are mostly imperfect.

* The following note is added by Mr. E. R. Gee who has seen the manuscript prior to sending it to the Press :—" There appears to be some slight confusion in the nomenclature of the 'Speckled Sandstone' sequence. A. B. Wynne originally included the Talchir conglomerates together with certain outcrops of what have since been termed 'Conularia Beds' of the eastern parts of the Range in his *Speckled Sandstones*; but he omitted the Talchirs of the western areas. Later authors have in some cases used the term 'Speckled Sandstones' to include the whole sequence from the base of the Talchirs up to the upper limit of the Lavender Clays, though others have adopted it to include only the sandstones and clays overlying the fossiliferous olive-green and grey sandstones and shales (the 'Conularia Beds') that follow the Talchir conglomerates. For the complete sequence from the Talchirs up to the base of the Productus Limestones, the name 'Speckled Sandstones' is certainly not appropriate and I, therefore, propose to adopt, in my description of Salt Range stratigraphy, a slightly revised classification, retaining the term 'Speckled Sandstones' for the *stage* which underlies the Lavender Clays. For the whole sequence, I propose the name 'Nilawan series' after the ravine in which the succession is so well exposed. My proposed classification is as follows :—

(Productus Limestone series.)

Nilawan Series . { Lavender Clay stage.
Speckled Sandstone stage.
Conularia Beds.
Talchir Conglomerates.

The fossils described by Dr. Reed occur within the Conularia Beds, that is to say, the horizon is regarded as equivalent to that in which the marine fossils, *Conularia* and *Eurydesma* occur in the eastern parts of the Salt Range."

This collection is of special interest because non-marine lamellibranchs have not been found previously in India associated with the Gondwana flora, and none have been found in any of the Gondwana beds except the few specimens discovered by Gregory (1923, p. 153) in black shales at Martaban Station in Burma which Weir (1938, p. 14, pl. I, figs. 5-9) has recently described and figured more in detail. Gregory referred them to *Palæanodonta okensis* Amalitsky, and to *P. subcastor* Amal., but Weir gives other identifications.

In South and East Africa the plant-bearing Karroo beds have long been known to contain some non-marine lamellibranchs in a few places which have been described or mentioned by various authors. The more recent papers dealing with the later collections from East Africa are those by Cox (1932) describing those from the Ruhuhu Coalfield and from the Ruhembe beds (1936) in Tanganyika Territory, and that by Weir (1938) redescribing Gregory's Kenya species of *Palæanodonta* as *P. fischeri* Amal. with the aid of more material from the Sabaki River, Kenya, where Gregory (1921) had previously collected the specimens.

But most of the specimens from South Africa and Tanganyika which the author has examined are in quite a different state of preservation to those in this collection, though those from Nyasaland are in this respect similar. The Burma specimens collected by Gregory occur in black shales and may indicate the same horizon as in the Salt Range, though the determination of identical species is uncertain.

It should be mentioned that Grabau (1924, pp. 485-487, text-figs. 303*a-e*) figured three new species of *Carbonicola* and *Anthracomya* from the Upper ? Permian (Hukou Shale) of the Fukien province in China. The similarity of *Anthracomya* and *Palæanodonta* and the doubts about the shells referred to the genus *Carbonicola* which Cox (1936) has expressed in connection with certain Tanganyika specimens leads one to suspect that in the Hukou Shale these fossils may belong to the same genera or even some of the same species as the Burma and Indian shells or at any rate be closely allied to some of them.

The identity of many of the African lamellibranchs with those from Russia described by Amalitsky from the Permian of the

Oka-Volga basin was maintained by Amalitsky (1895) and has been recently further established by Cox (1932, 1936), but we may remark that several of those described by Tschernyschew (1931) from the Donetz basin may be compared rather with the present Salt-Range examples, though we may doubt if any are identical. Amalitsky identified Gregory's specimens from Kenya with the Russian *Palæanodonta fischeri* Amal., and Weir (1938) refers them at any rate to the same group of species and he suggests the correlation of the Martaban Shales with the Upper Permian (Tartarian) of the Oka-Volga basin. But Schmidt's (1905) assemblage of species of *Palæanodonta*, some of which are probably identical with our species, occur in the Rothliegende and therefore are of Lower Permian age.

The succession of the beds at Kathwai given by Mr. Gee is as follows in descending order :—

(*Speckled Sandstones*, middle and upper portions).

(1) Green and reddish massive sandstones with red and purple clays of the lower part of the Speckled Sandstone stage. Massive dull-green sandstone at the base.

Conularia Beds.

(2) Grey and black carbonaceous shales, sandy in the lower part, including in the upper portion fairly well preserved impressions of *Glossopteris*, *Gangamopteris*, etc. : also a few small lamellibranch casts; total thickness 25 to 28 feet; fossils in the upper part.

(3) Grey and buff flaggy friable sandstones alternating with thin grey sandy shales, carbonaceous above; 9 feet.

(4) Talchir boulder-bed, including boulders ranging up to nearly 2 feet in diameter; thickness varying from 6 inches to 2 feet.

(Purple Sandstone series, massive maroon and buff-coloured sandstones.)

The fossils described below came from bed No. 2.

DESCRIPTION OF SPECIES.

Genus PALAEOMUTELA Amalitsky.

Palæomutela cf. *oblonga* (Jones).

Plate 23, figs. 19, 20.

The species from the Ruhuhu Coalfield which Cox (1932, p. 626, pl. XXXIX, figs. 5, 6) identifies with *Iridina ? oblonga* Jones (1890

(2), p. 556, text-fig.) from north-west of Lake Nyasa seems to be represented by several specimens. Newton previously described (1910, p. 243, pl. XIX, figs. 11-14) and figured it from Nyasaland. The redefinition of the species given by Cox (*op. cit.*) need not be repeated, as our specimens agree closely with his from Tanganyika and from Nyasaland.

Specimens Nos.—K41/666, K41/667.

Palæomutela cf. *neglecta* (Jones).

This species seems to be separable from *P. oblonga* with difficulty, but there are some poorly preserved impressions or casts (K33·598) which appear to resemble in shape those figured by Cox (1932, p. 628, pl. XXXIX, figs. 7-10) from the Ruhuhu Coalfield who considers this African species to agree very closely with the Russian species *P. keyserlingi* Amalitsky (1892, p. 168, pl. XXI, figs. 9-14).

Palæomutela cf. *subparallela* Amalitsky.

Plate 23, fig. 8.

Several small specimens 9-10 mm. in length seem to be comparable with the Karroo form figured and described by Cox (1932, p. 627, pl. XXIX, figs. 1-3) as *Palæomutela subparallela* Amal. (1892, p. 164, pl. XXI, figs. 39-44), but the hinge-line and dentition are in no case visible and we have to rely on the general shape and characters.

Specimen No.—K41/668.

Palæomutela cf. *rectodonta* Amalitsky.

Plate 23, figs. 6, 12, 15.

The truncated posterior end of this species (Amalitsky 1892, p. 169, pl. XXI, figs. 18-23, 27, 28) is characteristic, but as Cox (1932, p. 629, pl. XXXIX, figs. 11-15) remarks in describing and figuring examples from the Ruhuhu Coalfield there are specimens intermediate between the typical form and that which he refers to *P. neglecta* (Jones), and he further says "the delimitation of species of this group is a difficult question". Cox (*op. cit.*) has given a fresh and emended definition of this species with which he includes,

P. orthodonta Amal. and its varieties. The pseudo-dentition is not visible in any of our specimens.

Specimen Nos.—K41/669, K41/670, K41/671.

Palæomutela ? singularis sp. nov.

Plate 23, fig. 3.

Shell transversely suboval; anterior and posterior ends equally rounded; valves gently convex without any umbonal ridge; umbones low, broad, situated at about one-third the length of the shell. Surface covered with concentric striæ becoming stronger towards the margin.

TEXT-FIGURE 1.—Outline of *Palæomutela ? singularis.*

Dimensions—

Length	11·5 mm.
Height	4·5 mm.

Remarks.—None of the specimens are very well preserved or complete, but the oval shape of the shell and the position of the umbo rather far back from the anterior end distinguish it from all the other species except *Palæomutela subparallela* Amal. as figured by Cox (1932, p. 627, pl. XXXIX, figs. 1-3) from the Karroo beds of Tanganyika Territory, though the Norwegian form which Dix and Trueman (1935, pp. 28, 29, text-figs. 2*a*-*e*) compare with *Palæanodonta castor* Eichwald looks much like them. We may also compare the shells from the Rothliegende which Schmidt 1905, p. 51, t. V, fig. 5) figured as *P. verneuili* (Amalitsky), though they do not resemble Amalitsky's figures of that species. But on the whole we may more probably refer it to the genus *Palæomutela.*

It is interesting to note that in Norway there are found fragments of the fish *Elonichthys* associated with the lamellibranchs compared with *P. castor* as in the case of the Salt Range.

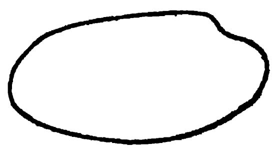
Specimen.—G. S. I. Type No. 16751.

Genus PALÆANODONTA Amalitsky.

Palæanodonta salaria sp. nov.

Plate 23, figs. 1, 2.

Shell transversely elongated, ovate; dorsal margin long, gently arched; ventral margin more arched; posterior end broadly rounded subtruncate; anterior end rather smaller, more sharply rounded, projecting; pre-umbonal margin very slightly excavated; umbo low, blunt, directed forwards, situated at about one-fourth length of shell. Surface of valves crossed by very weak diagonal ridge dying out behind.



TEXT-FIGURE 2.—Outline of *Palæanodonta salaria.*

Dimensions—

Length	10·0 mm.
Height at posterior end	5·0 mm.
Height at umbo	4·0 mm.

Remarks.—This form agrees best with the specimen from Martaban Station, Burma, figured by Weir (1938, pl. I, fig. 6 non cet.) as *P.* cf. *fischeri* Amal. but it also much resembles *Anthracomya bellula,* Bolton (1897, p. 4, pl. V, fig. 5) from the Coal Measures of Lancashire. It resembles in shape *Kidodia stockleyi* Cox (1936, p. 52, text-fig. 1) from Tanganyika, but we do not know its hinge.

Specimens.—G. S. I., Type Nos. 16752, 16753.

Weir has pointed out the great apparent variability in the non-marine Upper Palæozoic lamellibranchs, particularly those of the genus *Palæanodonta* and the consequent wide or even diverse interpretation of specific or even generic limits which different authors have adopted. Thus Amalitsky, Cox, Schmidt and Weir hold independent and more or less divergent views about the specific reference of many of the shells which have been described from widely separated localities. In many cases the specimens seem to be too poor and unsatisfactorily preserved for precise determination,

In the face of such disagreement and uncertainty it appears safer to give distinctive specific names to such of the Salt Range forms which can be satisfactorily recognised, even at the risk of such forms being ultimately held to be only varieties of other established species.

Genus CARBONICOLA McCoy.*

Carbonicola ? indica sp. nov.

Plate 23, fig. 22.

Shell transversely elongated, about twice as long as high; dorsal margin straight, about two-thirds the length of the shell; posterior end obliquely truncate with lower angle subacute; ventral margin rather strongly arched, sweeping up in front into short rounded anterior end; umbo low, situated at about one-fifth the length of the shell from the anterior end; a weak straight diagonal umbonal ridge crosses the valves from the umbo to the posterior lower angle.

Dimensions—

	G. S. I. Type No. 16754.
Length	11·5 mm.
Height (max.)	5·7 mm.

Remarks.—This species appears to be most nearly related to *Carbonicola angulata* De Ryckhot, as figured by Tschernyschew (1931, pp. 25, 91, t. II, figs. 37-39, 45) and to *C. similis* Brown, as also figured by him (1931, pp. 27, 92, t. II, figs. 42-44, t. III, figs. 47-52) from the Donetz basin, but the ventral margin in our species has a stronger curve so that the shell is highest in the middle. In view of the considerable difference of opinion as to the degree of variability of the European species of *Carbonicola* and of the precise limits of the established species it appears desirable to designate these Indian forms by distinctive names.

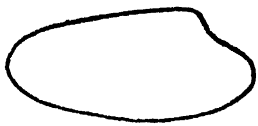
Carbonicola ? semielliptica sp. nov.

Plate 23, figs. 18, 21.

Shell transversely semielliptical, about twice as long as high, not widening posteriorly; dorsal and ventral margins parallel;

*NOTE.—It is possible that some of the species here doubtfully placed in the genus *Carbonicola* may belong to the genus *Palaeanodonta*.

dorsal margin straight, about two-thirds length of shell; ventral margin gently arched; anterior end small, sharply rounded, projecting, with rather long oblique slightly excavated pre-umbonal edge; posterior end rounded; umbo broad, slightly elevated above hinge-line, somewhat swollen, directed forwards, situated at about one-third length of shell. Surface of valves rather swollen and having a weak diagonal umbonal ridge distinct near umbo but dying out before reaching posterior lower angle of valve, the surface above it somewhat flattened and inclined. Concentric growth-striæ of unequal strength over whole surface.



TEXT-FIGURE 3.—Outline of *Carbonicola ? semielliptica.*

Dimensions—

Length	8·0 mm.
Height at umbo	4·25 mm.

Remarks.—This species appears more to resemble species of *Carbonicola* rather than any species of *Palæanodonta,* and several of the Coal Measure species may be compared. Thus we may specially note its resemblance to some varieties of *C. aquilina* Sow. (Hind, 1894, p. 69, pl. IX, figs. 1, 2) and to some of Tschernyschew's examples of *C. angustata* De Ryckh, (Tschernyschew, 1931, pp. 25, 91, t. II, figs. 37-41, 45). But *Palæanodonta subcastor* (Amal.) as interpreted by Cox (1936, p. 45, pl. V, figs. 5-7) and *P. parallela* (Amal.) (Cox, 1936, pl. V, figs. 2-4) from Tanganyika appear to be much like our specimens.

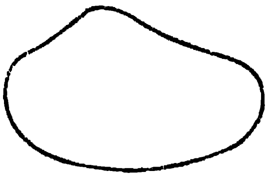
Specimens.—G. S. I. Type Nos. 16755, 16756.

Carbonicola ? recondita sp. nov.

Plate 23, figs. 4, 5.

Shell transversely suboblong, rounded, moderately convex, without any definite umbonal ridge but with a shallow submedian transverse depression or groove extending from the umbo to the ventral margin which it meets nearly at right angles; posterior end rather more sharply rounded and smaller than anterior end

which is broadly rounded; cardinal angles rounded; ventral margin gently arched; umbo low, broad, obtusely rounded, situated at about two-fifths the length of the shell, scarcely directed forwards, umbonal ridge low, weak, rounded, undefined. Surface of valves having rather regular narrow rounded rugæ set rather wide apart with fine concentric striæ on them and in interspaces.



TEXT-FIGURE 4.—Outline of *Carbonicola ? recondita.*

Dimensions—

Length	11·0 mm.
Height at umbo	7·0 mm.

Remarks.—There are two examples of this species, both consisting of left valves. They bear a great resemblance to *Carbonicola oslancis* Wright (1929, p. 38, pl. II figs. 5, 5A, 5B: 1931, p. 139, fig. 50A) and *C. similis* Brown (Wright, 1931, p. 139, fig. 50B) from the British Coal Measures, while *Oligodon gcinitzi* Amal. and its varieties (1892, p. 182, t. XXII, figs. 6-10), are much like them in external characters, but we are in ignorance of the hinge-characters and dentition of our examples, so it seems necessary to refer them to *Carbonicola.* We may compare our species also with *C. turgida* (Brown) (Hind, 1894, p. 66, pl. VIII, figs. 8-25) and *C. ovalis* Mart. (Hind, 1894, p. 56, pl. IV, figs. 18-22, pl. V, fig. 38) and *C. ventusta* Tschern. (1931, pp. 15, 86, t. 1, fig. 18).

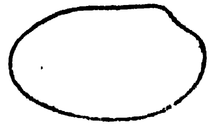
Specimens.—G. S. I. Type Nos. 16757, 16758.

Carbonicola ? kathwaiensis sp. nov.

Plate 23, figs. 14, 16.

Shell transversely suboval, highest in middle; anterior end rather sharply rounded and projecting, scarcely excavated at all in front of umbo; posterior end subequal but obliquely subtruncate; dorsal margin gently arched, nearly straight; ventral margin more strongly arched passing up gradually into posterior end; umbo small, very

low, scarcely rising above dorsal margin, situated forward at about one-fourth to one-fifth the length of the valve. Surface of valves very gently convex without any umbonal ridge, but with a slight flattening across middle of length; concentric growth-striæ of rather unequal strength over whole surface.



TEXT-FIGURE 5.—Outline of *Carbonicola ? kathwaiensis.*

Dimensions—

Length	7·5 mm.
Height	4·5 mm.

Remarks.—The almost oval shape of this species and low umbo makes it resemble *Carbonicola nucularis* Hind (1894-96, pl. VII, figs. 24-42) and some examples of *C. communis* Davis and Trueman (1927, p. 223, pl. XVI, fig. 6, text-figs. 2-5), both of which species occur in the British Coal Measures. But *C. faba* Wright (1931, p. 143, fig. 54; Wood, 1937, p. 10, fig. 6*f*) seems most like it. *Carbonicola eichwaldiana* De Vern. (Amalitsky, 1892, p. 151, t. XIX, figs. 24-26) also bears some resemblance. It does not seem like any species of *Palaeanodonta*, and Cox (1936) has been doubtful whether several Permian forms from Tanganyika should not be put in *Carbonicola*, so that we may provisionally place it in this genus.

Specimens.—G. S. I. Type Nos. 16759, 16760.

Genus ANTHRACOMYA SALTER.

Anthracomya shahpurensis sp. nov.

Plate 23, fig. 7.

Shell transversely elongated, widening slightly to posterior end; anterior end projecting, sharply rounded; posterior end more broadly rounded; dorsal margin nearly straight; pre-umbonal margin slightly excavated; umbo low, broad, directed forwards, not rising above hinge-line, situated at less than one-fourth the length of the

shell from anterior end; ventral margin slightly oblique, nearly straight, not parallel to dorsal margin, and having a wide shallow emargination at about half its length. Surface of valve gently convex, with a broad very shallow depression running and widening from the umbo to the emargination of the ventral margin and immediately in front of the weak low rounded umbonal ridge. Concentric striæ rather strong on whole surface.

TEXT-FIGURE 6.—Outline of *Anthracomya shahpurensis.*

Dimensions—

Length	9 mm.
Height at umbo	4 mm.

Remarks.—There is only one specimen of this species consisting of a complete right valve. We may compare the Coal Measure species *A. modiolaris* Sow. (Hind, 1895, p. 95, pl. XIV, figs. 1-32; Pruvost, 1913, p. 195, pl. VIII, figs. 9-12) from Britain, France and Russia (Tschernyschew, 1931, pp. 31, 94, t. III, fig. 53), but ours has a weaker and more rounded umbonal ridge. The species which appears to be almost identical is *Anthracomya pruvosti* Tschernyschew (1931, p. 99, t. IV, fig. 69) as figured by Weir and Leitch (1936, pp. 744-745, figs. 15*a-h*) from the "Barren Red Measures" of the River Clyde, Bothwell, Scotland.

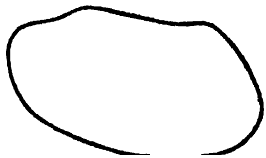
Specimen.—G. S. I. Type No. 16761.

Anthracomya subquadrata sp. nov.

Plate 23, figs. 10, 13.

Shell obliquely subquadrate; hinge-line straight; posterior cardinal angle obtuse; anterior cardinal angle subrectangular; ventral margin gently arched, oblique, nearly straight in middle; anterior end of shell abruptly rounded; posterior end wider, broadly rounded, obliquely truncated above; umbones broad, low, subcentral, nearer anterior than posterior end; surface of valves very gently convex,

somewhat flattened posteriorly, without any umbonal ridge; ornamented with fine, concentric growth-lines of rather unequal strength.



TEXT-FIGURE 7.—Outline of *Anthracomya subquadrata.*

Dimensions—

Length of shell (oblique)	8·0 mm.
Length of hingeline	6·0 mm.
Height of shell at front end	2·5 mm.
Height of shell at posterior end	4·0 mm.

Remarks.—This species resembles in shape *Anthracomya modiomorphoides* Grabau (1923-24, p. 485, text-fig. 303*e*) from the Hukou shale (Upper ? Permian) of the Fukien province of China, but it has not any umbonal ridge. The British species *A. adamsi* Salt (Hind, 1896, p. 89, pl. XII, figs. 1-19) and *A. hindi* Wright, which are very variable (Trueman, 1938, pp. 459-469, text-figs. 1*a-d*, 3*a-e*) may be specially compared with our species. As Weir (1938, p. 13) remarks the Kenya specimens of *Palæanodonta fischeri* are "strongly reminiscent of certain *Anthracomya* of the Upper Carboniferous", and he reminds us that Dix and Trueman (1935, pp. 27 and 31) have drawn attention to the difficulty of discriminating between *Palæanodonta* and certain members of *Anthracomya*. Our species resembles the form from Martaban Station, Burma, which Weir figures as *Palæanodonta* sp. nov. ? (1938, p. 14, pl. 1, fig. 8). We may note also the similarity of *A. glotæ* Weir & Leitch (1936, pp. 745, 746, figs. 15*i*, *j*) from the Coal Measures of Scotland.

Specimens.—G. S. I. Type Nos. 16762, 16763.

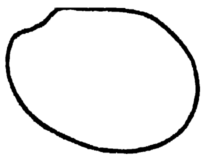
Genus ANTHRACONAUTA Pruvost.

Anthraconauta punjabica sp. nov.

Plate 23, fig. 9.

Shell obliquely suboval, widening posteriorly; umbo small, low, broad, scarcely rising above dorsal margin, situated at about one-

fourth the length of the shell; pre-umbonal margin short, slightly excavated; anterior end sharply rounded, passing into strongly arched oblique ventral margin sweeping up behind into broadly oval posterior end projecting behind; post-umbonal dorsal margin short, less than half length of valve. Surface of valves gently convex, most so in umbonal region, and crossed by numerous narrow thick concentric lamellose rugæ of rather unequal strength.



TEXT-FIGURE 8.—Outline of *Anthraconauta punjabica*

Dimensions—

Length (oblique)	8·5 mm.
Height (max.)	7·0 mm.

Remarks.—There is only one well preserved and perfect left valve of this species which seems to resemble most nearly *Anthraconauta scotica* (Etheridge junr.) from the British Carboniferous which Hind figured and described (1895, p. 123, pl. XVI, figs. 17-19) as a variety of *Anthracomya lævis*, but Weir and Leitch (1936, p. 746, text-figs. 14*k-m*) regard it as a distinct species belonging to the genus *Anthraconauta* Pruvost (1930, p. 247), the type of which is *Unio* [*Anthracomya*] *phillipsi* Williamson, (1836), a species fully described by Dix & Trueman (1931, p. 185, pl. XVII, fig. 1, text-fig. 3) with several varieties.

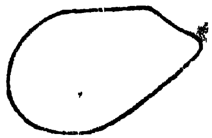
Specimen.—G. S. I. Type No. 16764.

Anthraconauta tenuistriata sp. nov.

Plate 23, figs. 11, 17.

Shell obliquely obovate, widening posteriorly; anterior end small, sharply rounded, projecting; umbo low, very broad, scarcely rising above dorsal margin, situated at about one-third length of shell; pre-umbonal edge oblique, scarcely excavated; ventral margin rather strongly curved, sloping down obliquely to broadly rounded posterior end; post-umbonal dorsal margin straight, with very obtuse

or rounded posterior angle. Surface of shell gently convex and marked with fine concentric striæ of rather unequal strength.



TEXT-FIGURE 9.—Outline of *Anthraconauta tenuistriata.*

Dimensions—

Length (oblique)	8·0 mm.
Height (max.)	5·0 mm.

Remarks.—The cast and impression of a right valve of this species are well preserved. It differs from *A. punjabica* in its more elongate form and fine concentric striæ instead of thick rugæ.

Specimens.—G. S. I. Type Nos. 16765, 16766.

Genus CYTHERELLA Bosquet.

Cytherella sp.

There are some very minute ostracods occurring rarely on some of the fragments of shale which by their shape and contour may be referred to the genus *Cytherella,* but their specific relations are uncertain.

CONCLUSIONS.

The above described lamellibranchs include a few species which are known from various Permian horizons in other lands as well as several new species allied to others from Upper Carboniferous (Coal Measures) horizons. The stratigraphical position and relations of the shale in which they occur indicate a Lower Permian age, and the association with the *Gangamopteris* flora confirms it.

It may be remarked that owing to the diverse opinions as to the specific reference of many of the specimens belonging to the genera *Palæomutela, Carbonicola* and *Palæanodonta* in Europe, Africa and China and because of our ignorance of the internal characters and

dentition of our Salt Range species it is difficult and unsatisfactory to use them for stratigraphical correlation. But there seem to be many allied or even identical forms in the Coal Measures and Rothliegende of Europe. The few specimens from the Martaban Station in Burma suggest that we are dealing with the same horizon in the case of the Salt Range.

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EXPLANATION OF PLATE.

All figures × 3.

FIG. 1. *Palæanodonta salaria* sp. nov. Right valve, internal cast. No. 16752.

FIG. 2. *Palæanodonta salaria* sp. nov. Right valve, internal cast. No. 16753.

FIG. 3. *Palæomutela singularis* sp. nov. Right valve. No. 16751.

FIG. 4. *Carbonicola ? recondita* sp. nov. Left valve. No. 16757.

FIG. 5. *Carbonicola ? recondita* sp. nov. Left valve. No. 16758.

FIG. 6. *Palæomutela* cf. *rectodonta* Amal. Right valve, internal cast. No. K41·669.

FIG. 7. *Anthracomya shahpurensis* sp nov. Right valve. No. 16761.

FIG. 8. *Palæomutela* cf. *subparallela* Amal. Right valve, internal cast. No. K41·668

FIG. 9. *Anthraconauta punjabica* sp. nov. Left valve. No. 16764.

FIG. 10. *Anthracomya subquadrata* sp. nov. Left valve. No. 16762.

FIG. 11. *Anthraconauta tenuistriata* sp. nov. Right valve. No. 16765.

FIG. 12. *Palæomutela* cf. *rectodonta* Amal. Right valve, internal cast. No. K41·670.

FIG. 13. *Anthracomya subquadrata* sp. nov. Left valve. No. 16763.

FIG. 14. *Carbonicola ? kathwaiensis* sp. nov. Right valve, impression of exterior. No. 16759.

FIG. 15. *Palæomutela* cf. *rectodonta* Amal. Right valve, internal cast. No. K41·671

FIG. 16. *Carbonicola ? kathwaiensis* sp. nov. Right valve, internal cast. No. 16760

FIG. 17. *Anthraconauta tenuistriata* sp. nov. Left valve. No. 16766.

FIG. 18. *Carbonicola ? semielliptica* sp. nov Left valve. No. 16755.

FIG. 19. *Palæomutela* cf. *oblonga* (Jones). Right valve, internal cast. No. K41·666

FIG 20. *Palæomutela* cf. *oblonga* (Jones). Right valve, internal cast. No. K41·667.

FIG. 21. *Carbonicola ? semielliptica* sp. nov. Right valve. No. 16756.

FIG. 22. *Carbonicola ? indica* sp. nov. Left valve. No. 16754.

ON *PALMOXYLON KAMALAM* RODE, FROM THE DECCAN INTER-TRAPPEAN SERIES WITH SPECIAL REFERENCE TO THE IMPORTANCE OF GROUND TISSUE IN THE CLASSIFICATION OF PALMS. BY V. B. SHUKLA, M.SC., *Department of Botany, College of Science, Nagpur, C. P.* (With Plates 24 and 25 and Text-Figure 1.)

CONTENTS.

INTRODUCTION.

Though, ever since the beginning of the twentieth century, petrified palms from India have attracted the attention of some foreign workers, it was not before 1918 that work on Indian fossils was done by workers in this country. Of a few accounts published in the nineteenth century one of the earliest was one by Nicolls on a long fossil palm stem discovered near Saugor, Central India, by Spry in 1833. This account was reprinted by J. H. Carter in 1857 (pp. 614-620). In this article Capt. Nicolls also gave an interesting account of the locality where this palm was found and of the geology of the place. He mentioned the discovery of numerous fossil fragments, mostly stems and root pieces.

Rev. S. Hislop, in his valuable account on the Geology of Nagpur (1853, pp. 58-76) while dealing with the numerous genera of fossil stems, roots, fruits and leaves, also mentioned the discovery of two genera of palms—' one *Nipadites* and the other a transparent piece

of chalcedony whose place in the order could not be exactly assigned' (p. 68).

In the year 1864 Medlicott (p. 97) discovered several plant remains from the Kasauli beds which are probably of Middle Tertiary age and in this collection he identified a representative of the artificial genus *Flabellaria* based on leaf impressions of palms. In 1882, Feistmantel (p. 52) identified specimens of leaf impressions brought by Mr. Lydekker from the Murree beds at Chakoti, Jhelum valley, in the northern Punjab and thought it to be 'very close and probably identical with *Sabal major* Heer'. He also investigated some other fragments of palm leaves from the Kasauli beds and amongst them also, he could identify one good specimen which agreed best with *Sabal major* Heer. In 1910 the discovery of this species was again recorded by Pilgrim (1910, p. 188) at Murree and in the parallel beds of Kasauli Series.

In 1882 Schenk (pp. 355-356) had also described two species of fossil palms from the Central Provinces, *viz.*, *Palmoxylon blanfordi* and *Palmoxylon liebigianum* and introduced the generic name *Palmoxylon* for including the different species of petrified palm stems. Later, Stenzel (1904, pp. 251-255) redescribed these two species, along with many others from different parts of the world in his important memoir 'Fossile Palmenhölzer' and established an artificial system of classification for their identification.

In 1920 Prof. Sahni began the investigation of different species of petrified palms from India and announced the discovery of a new species *Palmoxylon wadiai* from the Siwalik Hills in 1922 (p. 123). A preliminary account of about a dozen new species has been published by Prof. Sahni since then (1932, pp. 140-144*b*), and a detailed account of all these, along with several others which have recently been discovered, is under preparation.

Prof. Rode (1933a, pp. 75-82 and 1933b, pp. 105-114) of Benares has also described a few interesting new species of petrified palms from the Deccan Intertrappean Series, *viz.*, *Palmoxylon sahnii*, *Palmoxylon hislopi* and *Palmoxylon kamalam*. Mr. Kaul (1935a, pp. 285-286 and 1935b, pp. 99-102; 1938, pp. 149-150) has been investigating the anatomy of living palms for the last five or six years.

The author, with encouragement from Prof. Sahni as a pupil, has collected hundreds of loose fragments of petrified wood, mostly

from the Deccan Intertrappean Series. Some of these are Dicotyledons, some palms and a few conifers. An account of these is expected to be published in due course.

The present account deals with the detailed description of one of Rode's new species, *P. kamalam.* Though the species has already been identified by Rode (1933a, pp. 81-83) yet the discovery of certain anatomical variations necessitated its further critical study.

The fossil wood of which the description is recorded here was kindly sent to the author for investigation by the Director of the Geological Survey of India along with several pieces of fossil Dicotyledonous woods. Nearly fifty more specimens of the same species were collected by the author himself from the same locality.

The locality where these fossils were found, lies in the reserve forest area between Pulpuldoh and Paraspani villages (21° 43′ Lat.; 79° 10′ Long.) in the Chhindwara district of the Central Provinces. Hundreds of plant remains, mostly Dicotyledonous and palm stems, are found here scattered on both the sides of the foot path in the jungle. The preservation of most of these is quite satisfactory.

The fragments are mostly found lying superficially on the soil, which is a product of sub-aerial weathering. The weathered soil forms a very thin mantle, just about 10 ft. in thickness at the centre of the area and nearly 40 ft. thick at the north and south ends.

The most abundant species found in this area is *Palmoxylon kamalam* Rode (1933a, pp. 81-83). Though our fragments resemble Rode's type specimen in certain respects, there are many points in which they differ considerably. Sections were made from specimens measuring about 6 to 10 inches in length and nearly 4 to 5 inches in diameter (Pl. 24, Fig. 1).

DESCRIPTION.

All the pieces are decorticated and they seem to be the parts of the central region of the trunk which evidently attained a large size. The fragments are mostly of a whitish brown colour and vary from a few inches to about 10 inches in length and from 1 inch to 6 inches in diameter. The external surface of the stems is not preserved in any of the specimens, hence no idea of the girth of the

trunk can be formed. The dermal and sub-dermal zones also cannot be made out. The fossils are silicified and their preservation is good. The following account is based on a single section measuring roughly 6″×4″ (See Pl. 24, Fig. 2).

Fibrovascular bundles.—The fibrovascular bundles are not uniformly distributed throughout the area (Pl. 24, Fig. 2) as observed by Rode in his material (1933b, p. 82). Their number in the external region of the section varies from 25 to 28 per sq. cm. (Pl. 24, Fig. 3) while in the middle of the same section the bundles are medium sized and their number is between 10 and 12 per sq. cm. (Pl. 24, Fig. 4). Further in the same section at a distance of 8 or 10 cms. towards the centre from the periphery the bundles may be quite small and yet they may be 22 to 25 per sq. cm. (Pl. 24, Fig. 5).

The general organisation of all the vascular bundles is practically uniform. Those in the external region are slightly elongated while the others in the central region are more or less round. The fibrous part which practically in every case is well preserved shows the *Complanata* type of base (Stenzel, 1904, p. 150).[1] Its sclerenchymatous fibres possess a fairly big central cavity (Pl. 25, Fig. 6) and the radiating pit canals passing through the thickened walls can be made out almost in every case on the inner edges of the fibres. The fibres appear polygonal in transverse section and measure on an average ·04 mm. in width. Those towards the xylem are comparatively narrower.

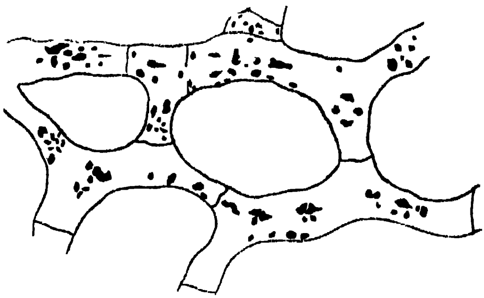
Vascular part.—The vascular part as compared with the fibrous one is practically insignificant and usually includes 3-4 vessels (Pl. 25, Fig. 7). The total diameter of vessels varies from ·1 mm. to ·25 mm. Phloem is usually not preserved.

Fibrous bundles.—Unlike Rode's material the fibrous part of the fibrovascular bundles is very satisfactorily preserved in these specimens but still no purely fibrous bundles are found in the ground tissue.

Ground tissue.—This is made up of narrow elongated cells which enclose big intercellular spaces. These cells are mostly of uniform

[1] Stenzel, K. G., (Fossile Palmenhölzer, p. 150, 1904) has used this terminology in his artifical classification of fossil palms. Those species in which the base of the sclerenchymatous part of the fibrovascular bundles is flat come under the *Complanata* group.

colour and some granular contents are seen inside them (Pl. 25, Fig. 8; Text-fig. 1).



TEXT-FIGURE 1.—*Camera lucida* drawing of some cells of the ground tissue with granular contents inside them (× 100).

The cells surrounding a fibrovascular bundle are arranged in a way so as to enclose more or less pentagonal, elongated intercellular spaces whose apices in some cases may be directed outwards. It is more due to these elongated intercellular spaces rather than the cells themselves as observed by Rode (1933a, p. 83) that one is reminded of the petaloid arrangement of a lotus flower after which the species is named. The cells may be rectangular, elongated, stunted or even Y shaped. The intercellular spaces which are separated by unicellular partitions assume a tendency to grow gradually bigger and polygonal as we recede from the fibrovascular bundles (Pl. 25. Fig. 7).

A remarkable feature of the ground tissue which can be made out even with the naked eye in the section is its irregular division into various elongated compartments along the planes of compression (Pl. 25, Fig. 9). The lines which appear to demarcate these compartments are thick and zigzag and are formed by the aggregation of crushed cells subjected to compression (Pl. 25, Fig. 10). The same kind of crushing before fossilization was described by Rode (1933b, p. 81).

DIAGNOSIS.

Ground tissue lacunose, divided by crushing into various irregular, zigzag compartments along the plane of compression. Cells usually narrow, elongated, rectangular, V or Y shaped, arranged

in a radial manner round the fibrovascular bundles, usually multiseriate ; intercellular spaces separated by unicellular partitions, the largest spaces being in the region between the two fibrovascular bundles and the smaller at the periphery. Fibrous bundles absent. Fibrovascular bundles varying in shape, form and distribution throughout the section, those at the periphery large, slightly elongated and densely arranged ; those 3-4 cms. towards the centre smaller, roundish and more scattered ; those further inwards very small and distributed quite uniformly ; fibrous part round, ovate or elongated and of the *Complanata* type ; vascular part 1/8 to 1/10 of the fibrous part in the case of the bigger bundles and 1/3 to 1/4 of the fibrous part in the case of smaller bundles.

Locality.—Reserve forest area between Pulpuldoh and Paraspani villages (Lat. 21° 43′ ; Long. 79° 10′) Sausar tahsil, District Chhindwara, Central Provinces.

Horizon.—Intertrappean Series of the Deccan.

Age.—Early Tertiary (Sahni, 1934, pp. 134-136).

COMPARISON AND DISCUSSION.

On the basis of the ground tissue and the shape of the fibrovascular bundles it seems probable that this species is the same as *Palmoxylon kamalam* Rode though there exist numerous differences in certain points. It is likely that these specimens might be from the central part of the big stem while the one described by Rode was more peripheral. The species belongs to the *Lacunosa* subgroup of the *Complanata* group in Stenzel's classification (1904, p. 150) and hence comparison has been confined to the other species described under the *Lacunosa* sub-group.

(*a*) The present species differs from *Palmoxylon remotum* (Stenzel, 1904, pp. 197-199) and *P. blanfordi* (Stenzel, 1904, pp. 192-195) in exhibiting a marked inequality in the sizes of the fibrous and the vascular parts of the bundles, though resemblances exist in the absence of fibrous bundles and separation of intercellular spaces by single cells.

(*b*) *P. hislopi* (Rode 1933a, pp. 76-80) differs from this species in having smaller intercellular spaces and in denser distribution of fibrovascular bundles (80-120 per sq. cm.).

(*c*) *P. texense* (Stenzel, 1904, pp. 185-186) also differs in possessing 40-50 fibrovascular bundles per sq. cm. and in

having the ratio of the vascular part to the entire fibrovascular bundle as 1 : 3.

(*d*) *P. lacunosum* (Stenzel, 1904, pp. 187-192) differs from the present species in showing the presence of fibrous bundles in the ground tissue and in having nearly one-third portion of the entire fibrovascular bundle occupied by the xylem.

(*e*) *P. boxbergæ* (Stenzel, 1904, pp. 195-196) also differs in possessing fibrous bundles and in larger size of the xylem in the fibrovascular bundle.

(*f*) This species again differs from *P. germanicum* (Stenzel, 1904, pp. 199-200) in having the cells of the ground tissue which are arranged in a radial manner round the fibrovascular bundles and in the marked inequality of the fibrous and vascular parts.

(*g*) *P. punctatum* (Stenzel, 1904, pp. 196-197) resembles this species in the absence of fibrous bundles but differs in having almost equal portions of the vascular and fibrous parts.

The internal organisation of this material also differs from that of Rode's specimen in certain respects. The fibrovascular bundles are neither uniformly distributed nor is their size always the same in this material as observed by Rode in his specimen. They are quite big and densely distributed on one side at the periphery (Pl. 24, Fig. 2-A). In the middle (Pl. 24, Fig. 2-B) they are small and quite sparse, while further inwards (Pl. 24, Fig. 2-C) they are very small and uniform in distribution. Further, in Rode's specimen the xylem forms, as a rule, one-half to one-third of the entire bundle, while in my material the xylem forms a very small portion in bigger bundles and hardly more than one-fourth in the smallest bundles.

Taking thus the forementioned features into account the two specimens evidently differ from each other in several respects and it might have been quite reasonable to class my material under a new species, particularly in view of the differences in the form, size and distribution of the vascular bundles. But on the other hand it is also clearly seen in the same section in my material that there are considerable variations in different portions as regards the form, size, shape and distribution of the fibrovascular bundles—a feature on which we often rely for the determination of the species.

Some of the variations observed between these different portions (A, B, C) of the same section (Pl. 24, Fig. 2) are indicated below :—

	Observations in different parts of the same section based on an average of 50 counts (See Plate 24, fig. 2.)		
	Region A.	Region B.	Region C.
Fibrovascular Bundles—			
Distribution per sq. cm. . . .	25—28	10—12	22—25
Dimensions in trans. section .	1·2×8 mm.	·6×·4 mm.	·4×·3 mm.
Form	Elongated.	Round.	Round.
Ratio between xylem and fibrous parts	1 : 11	1 : 8	1 : 4
Ground tissue—			
Dimensions of intercellular spaces in trans. section	·4×·33 mm.	·35×·32 mm.	·37×·31 mm.
Width of parenchymatous cells .	·1 mm.	·12 mm.	·09 mm.
Form of the cells	Rectangular, narrow, Y shaped or V shaped in all the three regions.		

From the variations shown in the above table I feel confident that the solitary block might easily have been described under two or three different specific names had it been broken up into the portions A, B and C at the very source (Pl. 24, Fig. 2). We are thus seriously warned against the reliability of the form, size, shape, etc., of the fibrovascular bundles in the determination of the species.

As we can make out from the above table, one important feature which has retained uniformity throughout the section represented in Pl. 24, Fig. 2 and other sections taken from my material, is the ground tissue. This tissue agrees quite closely with that found in Rode's material as well. I hence feel inclined to retain the present species under the old name *Palmoxylon kamalam* Rode and think that more value should be attached to the ground tissue for the identification of the species than to the other tissues.

Stenzel (1904, p. 123) has also noticed that in the different species of the fossil palms the structure of the ground tissue was quite distinctive but he could not make use of this feature as most of the

material at his disposal was not so well preserved as to show the nature of the ground tissue in the different parts of the same stem. Kaul (1935a, pp. 285-286) has also studied a large number of modern palms and has observed that the ground tissue is of primary importance. He feels that it was possible to classify the different genera on the basis of the ground tissue alone as the different species of a particular genus usually show one kind of ground tissue with insignificant variations. He (1938, pp. 149-150) lays stress upon the similarity in the ground tissue amongst the different species of various living genera, *e.g.*, *Phœnix*, *Rhapis*, *Borassus*, *Caryota*, *Areca*, etc., and has found that the artificial characters like form of sclerenchyma, number and position of fibrovascular bundles, etc., often go hand in hand with the natural characters of the ground tissue. In view of the similarity in the ground tissue between a few fossil and living forms, *e.g.*, *Palmoxylon coronatum* Sahni and *Borassus flabellifer* respectively or *Palmoxylon sundaram* Sahni and *Cocos* sp., he has suggested that these living and fossil forms respectively may not be generically different from each other.

While briefly reviewing Kaul's work Prof. Sahni (1938, pp. 162-163) has referred to the bewildering variety of structure shown by the different species of *Palmoxylon* which evidently need not be put under a single genus. He has further mentioned that the danger of creating spurious species is enhanced by the fact that the same stem may show varying characters in different parts. Prof. Sahni is of opinion that in view of the recent investigations we should be able to refer at least some well preserved species of *Palmoxylon* to natural genera of palms.

It is hence likely that several species of *Palmoxylon* which we have so far kept separate may ultimately have to be combined under one name, while several others may turn out to be so different that they may have to be referred to separate genera. The form, size, shape, distribution, etc., of the fibrovascular bundles may, however, be given a secondary place for the identification of the species.

SUMMARY.

In this paper the author gives a detailed account based upon an examination of about fifty specimens, of a species of *Palmoxylon* described by Rode as *P. kamalam* from the Deccan Intertrappean beds of the Chhindwara district.

A few sections from different specimens were studied. In one measuring nearly 6″×4″ it was found that there were considerable variations in the different parts of the same section in the shape, form and distribution of the fibrovascular bundles. The ground tissue, however, in all the regions of this section was of uniform nature. This tissue also resembled that found in *Palmoxylon kamalam* Rode but the fibrovascular bundles again differed considerably. In view of the fact that the nature of the fibrovascular bundles is not constant within the same section, the author feels inclined to think that these may not be considered as reliable features for diagnosing a species. More importance should be attached to the ground tissue. Hence, the present species has been referred to *Palmoxylon kamalam* Rode.

ACKNOWLEDGMENTS.

The author is much indebted to Prof. B. Sahni for his kind suggestions, criticism and constant help in connection with this work. My thanks are also due to Mr. K. N. Kaul, M.Sc., for some references to the literature and to the authorities of the Geological Survey of India for their kindly placing the material at my disposal and lending me some literature. I also gladly acknowledge the help given to me by the Nagpur University in getting some sections prepared for the purpose of this investigation.

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EXPLANATION OF PLATES.

PLATE 24, FIG. 1.—*Palmoxylon kamalam* Rode ($\times \frac{1}{2}$).

FIG. 2.—The entire transverse section showing three different portions of the section (A, B, C) each showing difference in size, shape and distribution of the fibrovascular bundles. A is the outermost region, C the innermost. ($\times \frac{1}{3}$).

FIG. 3.—Portion A from the transverse section showing dense distribution, large size and slightly elongated shape (in some cases) of the fibrovascular bundles (Nat. Size).

FIG. 4.—Portion B from the transverse section showing a very sparse distribution, medium size and round form of the fibrovascular bundles (Nat. Size).

FIG. 5.—Portion C from the transverse section showing very small size of the fibrovascular bundles which have a round form (Nat. Size).

PLATE 25, FIG. 6.—Sclerenchymatous portion of a fibrovascular bundle as seen in transverse section ($\times 300$).

FIG. 7.—A portion of the transverse section showing a fibrovascular bundle possessing three xylem vessels and the ground tissue surrounding it. The intercellular spaces gradually grow bigger and polygonal as we move away from the bundle ($\times 125$).

FIG. 8.—A portion of the ground tissue as seen in transverse section. The cells show some tiny flattened crystalline bodies inside them ($\times 300$).

FIG. 9.—A portion of the transverse section showing the irregular division of the ground tissue into elongated compartments along the plane of compression ($\times 20$).

FIG. 10.—A small portion of the ground tissue as seen in transverse section showing the aggregation of crushed cells subjected to compression which form thick zigzag lines to demarcate the irregular compartments in the ground tissue ($\times 125$).

THE GEOLOGY OF SOUTH RATNAGIRI AND PARTS OF SAVANTVADI STATE, BOMBAY PRESIDENCY. BY L. A. N. IYER, M.A. (MADRAS), PH.D. (LOND.), D.I.C., *Geologist, Geological Survey of India.* (With Plates 26—32.)

CONTENTS.

I.—INTRODUCTION.

Whilst examining certain mineral deposits in the Ratnagiri district and in the adjoining Indian State of Savantvadi the opportunity was taken to map the adjoining areas geologically. It was not possible to do the usual sheet mapping, but the parts examined in the different sheets No. 47H/11, 12, 15, 16 and 48E/9 and 13 of the Survey of India on the scale of 1 inch=1 mile form a continuous area. It comprises portions of the Malvan and Devgad *taluks*, Vengurla *Mahal* of the Ratnagiri district and the Indian State of Savantvadi.

Physical features, climate, fauna, etc.

The area in the Ratnagiri district can be roughly divided into three divisions, *i.e.*, (1) the coastal strip, often rocky and dangerous, with small bays, creeks and harbours and at times a little flat and sandy, (2) the central belt, which is also very hilly, mostly made up of the Deccan trap and laterite, some exposures of Kaladgi rocks, granites, *etc.*, greatly cut up by the numerous tributary streams and presenting a very complex topography, and (3) passing on to the steep wall-like ridges of the Sahyadris, which form the main topographical feature, bounding the eastern horizon from all points of observation. The Sahyadris (Pl. 26, figs. 1 and 2) show at their top separate flows of lava. In this area numerous springs of good water occur.

The lower hills are bare and treeless and whatever scrub grows on them is cut and burnt for manure by the villagers. The area, forming a rough tableland, is also dissected by deep valleys which are often occupied by mountain torrents.* Near the coast the tableland is almost bare except for narrow strips where mango, coconut, jack-fruit and other trees thrive.

Rivers and lakes.

The rivers generally have their origin in the Sahyadri hills or the various spurs connected with them and run through deep and narrow valleys. Their course is usually towards the west with a slight southerly tendency. The main rivers of this area are the Vaghotan reaching the Arabian sea at Vijaidrug (16° 33′ : 73° 23′), the Gad river which flows into the sea north of Malvan (16° 4′ : 73° 30′), and the Karli river which flows through the Karli creek into the sea. These rivers traverse a very hilly area which is further dissected by numerous tributary streams, but long ridges capped by laterite are the common feature. The rivers are tidal and are navigable for about 20 miles inland; the chief ports have grown up on their banks which form fertile land.

No natural lakes are present, but some artificial reservoirs have been constructed, as Dhamapur (16° 1′ : 73° 39′), Varad (16° 3′ : 73° 41′) and Pandur (16° 3′ : 73° 45′) in the Malvan *taluka*.

Scenery.

The Ghat sections, as near the Amba Ghat (16° 59′ : 73° 47′), Phonda Ghat (16° 23′ : 73° 52′) and Amboli Ghat (15° 57′ : 74° 0′), afford the finest views that the Sahyadris present (Pl. 26, figs. 1 and 2). Descent to the lower plateau brings one to the characteristic ridges of trap and

laterite, devoid of any vegetation. But along the valleys and near the coast a little vegetation is present providing better scenery. The coast has also a number of little creeks and harbours in the laterite area.

Climate.

The climate may on the whole be considered healthy, but there is no cold weather as in North India. From May to September the south-west monsoon gives abundant rain, about 150-200 inches per annum, and from November to February is the cooler weather of this area. From the beginning of February until the monsoon commences it becomes very hot. Malaria is present in some parts of the district and in the Savantvadi State.

Fauna and flora.

As there are no heavy forests, wild animals are rare, but at times leopards emerge from the jungle and prowl about the villages. The area is notorious for reptiles, as the large tracts of laterite with winding holes and cavities afford them ample shelter. One variety, locally known as *Fursa* (*Echis carinata*) is very dangerous and its bite fatal.

In Savantvadi some forests yield teak and other inferior timber. Wherever the laterite has a thin soil-cap, scrubby jungle and grass grow. In the valleys and fertile areas, paddy is cultivated, but the local crop is not sufficient for the annual needs of the population.

Communications.

The district has been fully supplied with a number of motorable roads in recent years. There are firstly the main roads that connect the important places and the coastal towns, (i) Kolhapur (16° 41′ : 74° 14′) to Malvan (16° 4′ : 73° 30′), *via* Phonda Ghat, and (ii) Belgaum (15° 53′ : 74° 30′) to Vengurla (15° 51′ : 73° 40′), *via* Amboli Ghat—78 miles. These roads are motorable throughout the year and, besides, a trunk road is under construction direct from Bombay to Goa through the Ratnagiri district. There are also other metalled roads and cart tracks from the interior villages connecting them with the coastal towns. During the fair season, there is also a daily coastal steamer service run by the Bombay Steam Navigation Co. and other companies from Bombay to Goa touching at all the Ratnagiri ports. All the services are kept busy, since the population of the district depends on Bombay for their livelihood and always moves up and down.

Previous literature and maps.

1. C. J. Wilkinson was the first to work in this area. His views are embodied in a paper, "Sketch of the Geological structure of the Southern Konkan". (*Rec. Geol. Surv. Ind.*, IV, Pt. 2, pp. 44-47, 1871.)

2. R. B. Foote. "The Geological Features of the South Mahratta Country and Adjacent Districts". (*Mem. Geol. Surv. Ind.*, XII, pp. 1-268, 1876.)

The information regarding the south Konkan is based on Mr. Wilkinson's work.

3. Sir L. L. Fermor. Reference to the occurrence of manganese ores in the trap rock *etc.*, (*Mem. Geol. Surv. Ind.*, XXXVII, p. 661, 1909.)

The iron ores of Goa and Ratnagiri. (*Rec. Geol. Surv. Ind.*, XLVI, p. 117, 1915.)

4. Sir Edwin Pascoe refers to the occurrence of Kaolin near Malvan in the Ratnagiri district. (*Rec. Geol. Surv. Ind.*, LV, p. 21, 1922.)

5. Dr. C. S. Fox discusses the nature of the laterite in this area in connection with his study of the bauxite deposits of India. (*Mem. Geol. Surv. Ind.*, XLIX, pp. 93-97, 1923.)

6. B. G. Deshpande. "Geology of Vengurla Peta, Bombay presidency." (*Proc. XXIVth Ind. Sci. Con.*, p. 231, 1937.)

Of the above-mentioned papers, Messrs. Wilkinson's and Foote's papers are the most important. Wilkinson gives a geological sketch of the area as well as the rock formations met with. The main rock formations described by him are the following:—the Deccan trap, sandstones, shales and underlying metamorphic rocks. In the Savantvadi State, according to him, denudation had removed most of the sandstones, which concealed the Older metamorphics, so that the trap is found capping the Older metamorphics. He does not give any correlation of the Konkan rocks.

Foote first deals with the Older gneisses, which include quartzites and schists of Wilkinson and also refers to the intrusion forming the Waraora hills (Waghere station of map), five miles east by north of Vengurla as composed of porphyritic syenite and hornblende rock.

He has given a fuller account of his Kaladgi system, in which he has included part of the rock formations of the Konkan described by Wilkinson.

The rocks belonging to this system are unfossiliferous, resemble the Cuddapahs, and have been preserved usually in the basin lying between the Kistna and the Malprabha rivers in the south Mahratta country. The name was given by Foote[1] from the town of Kaladgi (16° 12′ : 75° 34′) in the Bijapur district. The system in that district has been divided by him into a lower and upper series as follows :—

B.—*Upper Kaladgi series*—

6. Shales, limestones, and hematite-schist.
5. Quartzites, with local conglomerates and breccias.

A.—*Lower Kaladgi series*—

II—4. Limestones and shales.

I { 3. Sandstones and shales.
2. Siliceous limestone and cherty breccia.
1. Quartzite, conglomerate and sandstone.

The area west of the Ghats to the Arabian sea was mapped by Wilkinson, and east of the same by Foote, who gives a very exhaustive description of this series.[2] For the area west of this, he has used Wilkinson's account. He also gives an account of the Lora (16° 24′ : 73° 48′) inlier at the foot of the Phonda Ghat and also refers to several small inliers in the laterite plateau near the coast north of Vengurla. The upper series is confined to the Kaladgi basin itself, whereas the Lower Kaladgis occupy the whole of the western portion of the basin. There is a great deal of diversity of texture and colour in the Kaladgi rocks, the reason for this diversity being that the rocks have been derived from an older series from widely distant areas, the members of which itself were of diverse nature.

Foote considers the quartzites and sandstones of the Konkan as belonging to the lower Kaladgi group. He also refers to the Kaladgis at Achra (16° 13′ : 73° 30′) and Malvan in the Ratnagiri district.

Existing geological maps of the area.

There is no geological map illustrating Mr. Wilkinson's paper in the *Records*, but there is a geological map attached to Mr. Foote's

[1] R. B. Foote, *Mem. Geol. Surv. Ind.*, XII, p. 17, 70 (1876).
[2] *Op. cit.*, pp. 70-138.

memoir on the South Mahratta Country, which includes the area between latitudes 17° and 15° 30′ and from the Arabian Sea coast to longitude 77° 30′ on the east. In this paper, although some of the Kaladgi exposures are described in the text, in the portion of the geological map, the Deccan trap, coastal laterite and gneissic series have been shown. Thus all the pre-trappean rocks have been included under the gneisses.

II.—THE GEOLOGICAL FORMATIONS OF THE AREA.

Although Wilkinson and Foote described a number of rock types, the geological formations shown in their map are (1) laterite, (2) the Deccan trap, and (3) gneisses. For mapping purposes all the pre-trappean rocks were included by them under the gneisses. In the recent survey the pre-trappean rocks were examined in detail, and have been mapped separately. The following are the geological formations of the area:—

8. Alluvium.
7. Konkan laterite.
6. The Deccan trap.

Pre-Cambrian:

5. Metamorphic rocks (basic).
4. Basic intrusions,—dolerite, olivine-dolerite, olivine-gabbro, picrite and chromite-serpentine rocks.
3. Acid intrusions,—biotite-granite, gneiss, biotite-hornblende-granite coarse porphyritic granite and pegmatite.
2. The Kaladgi series (Cuddapah ?)
   - ii. *Metamorphic* group—phyllite, mica-schist and biotite-garnet-granulites.
   - i. *Arenaceous* group—Sedimentary—sandstones, conglomerate, micaceous sandstones and quartzite.
1. Archaean—Hematite-quartzite.

1. The Archæans.

The Archæans are the most ancient formation in the area, and are represented mostly by hematite-quartzite, which forms very small inliers with steep dips. A number of such small exposures

were noted in the recent survey but most of them are too small to be shown on the map. The following are some of the exposures :—

1. There is a small outcrop of hematite-quartzite east of the road from Kankauli (16° 16′ : 73° 45′) to Kasal (16° 9′ : 73° 44′) and east of Vagda (16° 14′ : 73° 45′) in sheet 47H/12 and 16 below the chromite hill.

2. In the same sheet E. N. E. of Kasal, dipping N. N. E at 70°-80°, there is a medium to coarse-grained quartzite made up of quartz and iron ore, the latter being more abundant. Other exposures were found S. S. W. of the village of Kunda (16° 9′ : 73° 46′) and a quarter of a mile E. N. E. of the same village (52/713, 714). The rocks are highly banded and made up of alternate bands of quartz and iron ore, the quartz being cemented with grains of hematite.

3. At 14 m. 1 fur., near Katta (16° 5′ : 73° 40′) a little banded ferruginous quartzite is present, as also at 11 m. 5 fur., near the road, and at one mile to the main road from Varad (16° 3′ : 73° 41′).

4. Two miles south of Malvan on the coast, a small exposure of ferruginous quartzite dips E. N. E. at 60°-70°.

5. Iron ore at Redi (15° 45′ : 73° 44′). This was the largest exposure of iron ore met with in the area and lies on the Vengurla-Goa boundary, about eight miles S. S. E. of Vengurla (15° 51′ : 73° 40′) on the coast. About 1½ miles S. S. W. of the path from Shiravda (15° 46′ : 73° 44′) and south of Redi in sheet 48E/10 and 14, there is a ridge running almost east to west with its lower slope covered by laterite. On the top of the ridge bedded iron ores, dipping N. N. E. at 35°, are seen. Following this ridge westwards towards the coast, the iron ore again passes into lateritic iron ore. At its western end and south of the village, the rock passes into thin-bedded sandstone dipping east at 30°.

2. The Kaladgi System.

The rocks under this group are the most important and interesting of the geological formations studied in this area on account of the variety of the rocks and the metamorphic derivatives due to the granite intrusions. The unmetamorphosed rocks, consisting of sandstones, quartzites, conglomerates, micaceous sandstones, *etc.*, were mapped at a number of places in sheets 47H/11 and 15, 47H/12 and 16 and 48E/9 and 13. Formerly, the rocks of this area were

supposed to consist of only sedimentary formations, but the present survey has proved that in part these have been intruded by acid and basic rocks, and have been subjected to contact metamorphism by the granite intrusions. Previously these granites and gneisses were considered to be metamorphic in origin and to underlie the whole of the area, and the intrusive nature of the granite was not recognised.

During the recent survey the sedimentary rocks and their metamorphosed derivatives were examined in detail. It has been possible to divide them into two series in the Ratnagiri district, *e.g.*, (1) unmetamorphosed sediments and (2) metamorphosed rocks. The two series of rocks form an asymmetrical fold or dome with the axis running from N. N. W.—S. S. E. and pitching N. N. W. under the trap and laterite north of the Gad river in sheet 47H/11. North of the road from Kasal to Malvan the southern termination of this dome is found, the top being covered by laterite with the metamorphosed rocks exposed at the bottom. South of this road a few small inliers of the granulite were noted. The dips are shallow west of the axis and steep east of the axis, probably due to the disturbance caused by the granite intrusion.

To the south-east a portion of another fold appears round Savantvadi (15° 54′ : 73° 52′) and east of Akeri (15° 56′ : 73° 49′), the rocks being disturbed and metamorphosed by the granite intrusions. But east of the granite intrusion unmetamorphosed sandstone was seen in the road-cutting on the Vengurla-Belgaum road.

Folding.

Connecting up all the exposures of rocks in the area three parallel folds, running N. N. W.—S. S. E. can be traced, portions of which are exposed in different places. The western and eastern folds are unmetamorphosed, but a portion of the central fold has been metamorphosed. A consideration of all these exposures leads to the conclusion that the Kaladgi basin was very extensive and might have been more or less continuous.

(a) *Lower Kaladgis—Unmetamorphosed rocks.*

The exposures are described from north to south, and the Phonda exposure comes first. Its maximum width is 4-5 miles from east to west and the length from north to south is about 5 to 5½ miles. Traverses were made along the two directions, but the road section gives a very clear idea of the structure.

Trap forms its eastern boundary at 45 m. 5 fur., on the Phonda road, overlying quartzites. Two miles west of this place, and west of the village, thin-bedded fragile sandy shales dip N. N. E. at 15°. At 48 m. 6 fur., it passes on to medium-grained white sandstones. In the western part of the exposure, a low ridge of sandstone runs E. S. E. with high dips towards the south-west, and shows irregular weathering. Here the rocks are pure white quartzites and sandstones passing down to finer grained buff sandstone at the base. In the first ridge the dip is north-east, and the scarp is formed on the western side. Towards Wadadawadi (16° 21′ : 73° 41′), the sandstone (52/691) weathers in huge boulders. A second ridge is also present with the sandstone dipping 20°-30° to the north-east. After a little alluvium the sandstone outcrops again at the village of Kondya (16° 21′ : 73° 48′).

Maldi (16° 12′ : 73° 36′).—Crossing the creek south of the village bedded sandstone was noticed dipping at 12°-20° W. S. W. The sandstone is medium-grained and white. The outcrop at one point is only 220 feet wide. It was found as far as one mile E. S. E. of Maldi, where it disappeared under the laterite. On the return journey to Kankauli, sandstone exposures were seen in the first stream and up to the second stream, and where the road and the Gad river approach. Sandstone also continued from Gotna to Varavda.

Kankauli to Kasal.—At point 27 m. 1 fur., and south of it shale with granite veins, and after 26 m. 6 fur., in a stream, shale and quartzite dipping W. S. W. at 40° were seen.

To Kumama and Golvan.—Proceeding from Katta (16° 5′ : 73° 40′) to Golvan (16° 8′ : 73° 37′) *via*, Kumama (16° 6′ : 73° 38′), beyond the valley a little white sandstone occurs. Some of the sandstone on the path shows ripple marking. This is followed by a little mica-schist and shale with south-south-westerly dip. Further up in the cutting bedded sandstone dips W. S. W. at 35°. The dip gradually turns west. At Golvan more sandstone was found and it continues to Naopat (16° 8′ : 73° 36′), where it passes under laterite.

Katta to Malvan.—On the road to Malvan, two miles west of Katta (16° 5′ : 73° 40′) a ridge approaches the road from the south. Along the ghat section, a dull white sandstone appears having a dip of 5° to W. N. W. or west. The bedding planes show ripple marks.

Malvan.—At Malvan near the coast, a series of sandstone, quartzite and conglomerate is found. These rocks dot the bay with dangerous reefs (Pl. 27, fig. 1). Dips vary from E. N. E. to north-east. It is found to be a rolling fold, pitching north or N. N. W. North of the custom house, an anticlinal fold of sandstone with conglomerate bands was seen. The current bedding of the sandstone and conglomerate bands prove their shallow water origin. The sandstone (52/732) and the conglomerate (52/731) are interbanded in the west, but near the custom house the conglomerate prevails. Further north behind the court house a rolling and pitching band of sandstone is present (Pl. 27, Fig. 2. and Pl. 28. figs. 1 and 2 Pl. VI, 1). The dip is here E. N. E. at 10°-15°. The conglomerate forms a very hard rock, made up of pebbles of quartzite or sandstone, oval, rounded or elongated, and varying in length from a half to one and a half inches. The matrix is dark and fine-grained.

Vaeran.—On the road to Vaeran (16° 10′ : 73° 37′) and north of the path turning to Masura, a little sandy fragile shale dips W. S. W. in the road cutting. From Vaeran to the stream cutting the road sandstone dips W. S. W. at 50°.

Hadi.—In the low ground near Hadi (16° 9′ : 73° 31′), the white sandstone has a N. N. W.—S. S. E. strike and dips W. S. W. In the well section west of the road the usual west-south-westerly dips prevail.

Valaval Hill.—△ 716, W. S. W. of Valaval (16° 0′ : 73° 39′) is a fine white quartzite, made up of medium-grained quartzite grains, which are angular and free from impurities.

Vengurla (15° 51′ : 73° 40′).—Exposures of Kaladgi sandstone are present in the Vengurla-Belgaum road, near the 74th. milestone, 72 m. 5 fur. and three-fourths of a mile south-east of a point 72 m. 2 fur. on the road, also south of 73 m. 7 fur. and west of Vetora (15° 55′ : 73° 43′). Some of the rocks contain pure white sandstone from which good sands for glass making could be extracted.

On the Bunder hill △ 260, in the north side at the base near sea level, a sandy shale dips N. N. W. at 60°, which on the top is covered by laterite. The sandstone fringes the coast on the west.

(b) *Lower Kaladgis-Metamorphic rocks.*

The metamorphic group consists of mica-schist, garnet-mica-schist, biotite-garnet-granulite and a little phyllite. These rocks

were met with mostly in the eastern portion of sheets 47H/12 and 16 and 48E/9 and 13. The rocks vary one from another, and are largely located near the granite intrusions, but, in the Savantvadi area, large inclusions of the granulite are perched on the granite itself, showing all stages of intermixture, and south of the same place the granite has soaked through the garnet-mica-schists, so that there can be no doubt about their origin—*i.e.*, contact metamorphism of the Kaladgi rocks by the granite. The unmetamorphosed rocks are confined to the western and eastern parts of the area, whereas the metamorphosed rocks are confined to the central areas, where the granite intrusions occur.

The schists were first seen in the Gad river south-west of Kankauli. A bed of quartzite striking N. N. W. to N. W. and dipping almost vertically, passes into garnet-mica-schist both on the eastern and western bank. The section along the Gad river, south-west of Kankauli has a number of exposures. Where the river takes a south-westerly bend, biotite granulite (52/708) dips north-east at 70°. The rock is composed of biotite, green and brown hornblende, felspar and quartz. After Satral (16° 15′ : 73° 44′) and following the stream, exposures of biotite-granulite dipping north-east at 40°-60° were noted; in this locality the rock breaks into slabs. At the junction of the Gad river and the Janauli stream biotite-schist and granulite dip at 40° to north-east.

In the stream north of Kasal (16° 9′ : 73° 44′) biotite-granulites dip E. N. E. at 40°. A specimen (52/712) near the Ovalya (16° 10′: 73° 41′) boundary, is dark grey in colour, composed of biotite, quartz and felspar and a little garnet. Protoclastic granulation is also present. The foot-hills south of the river have exposures of coarse porphyritic granite intrusive into the above rocks. River sections show exposures of the granulite in addition to quartzite. East of Kasal the granulite and quartzite pass under the trap. They appear again near Kunda and Kusba (16° 9′ : 73° 48′). Following the Kasal river towards Kalsuli (16° 12′ : 73° 48′) biotite-granulite dips E. N. E. at 40° in the stream.

At Amrad (16° 11′ : 73° 48′), in the fields, biotite-granulite dips at 50°-60° towards E. N. E. South of Amrad in the stream, some trace of current-bedding was noticed in the granulite.

From Kasal along the road to Kudal (16° 0′ : 73° 44′) some biotite-granulite appears, which is covered by trap on the east,

After Suklavadi (16° 6′ : 73° 42′) the dip changes to south-east and S. S. E.

Near Katta small granite intrusions are present in the granulite. The dip changes to south at 60°-70°. From Katta to Malvan, the granulite appears in stream sections.

Avalegam (16° 7′ : 73° 48′) and *Kadaval* (16° 8′ : 73° 49′). Four miles north-east of Kudal and east of the valley, biotite-schist and shale were seen to pass on to biotite-granulite. Here the dips are northwards at 70°-80°.

Akeri.—Near Akeri (15° 56′ : 73° 49′) biotite-schist dips S. S. E. at 70°-80° and is associated with a porphyritic granite. Local variations in dip are noticeable from N. N. E. to S. S. E. East of Akeri on the Belgaum road, at the col, the schist shows an anticlinal fold. Near 60 m. 2 fur. quartzite rocks dip south on both sides of the road

Near Danoli (15° 56′ : 73° 57′) the dip changes to north-west at 80°, and under the bridge pegmatite and sandstone are present. At 57 m. 5 fur. coarse biotite-granite with biotite-granulite inclusions appears as also at 58 m. 6 fur. on the same road as (52/754). At the margin of the inclusions large garnets are produced. These inclusions are fairly large and dip towards north-east. (52/768) is a specimen on the Danoli-Banda path, in which it is clear the garnets have been reconstituted from the biotite. The granulite appears in the streams.

Savantvadi-Araonda road.—At 3½ miles, where the road branches, biotite-granulite and mica-schist dip south at 50°-60°. Here the schist has been caught in the granite, the latter having soaked through the foliation planes of the schist. The same feature was also noticed in the Wadi-Banda road.

Savantvadi.—West of Savantvadi, the granite has inclusions of biotite-granulite on the northern slopes of the hills. Towards the W. N. W., isolated tors of such rocks are seen rising out of the granite. The weathered surface of the rock shows garnets projecting from it. On a fresh surface the garnets are seen to be full of inclusions, and are elongated in the direction of banding. The other mineral constituents are biotite, quartz, felspar, apatite and iron ore.

Mica-schist and garnet-mica-schist were seen at a number of places near the contact of the granite and the Kaladgi rocks, *e.g.* on the western face of the Vengurla Bunder hill, in the Gad river near Kankauli, west of the old Malvan road crossing. A

specimen (52/686) from this locality, is very coarse and schistose, mostly made up of biotite, quartz, a little felspar and garnets. Two and three quarters of a mile west of the granite contact in the Gad river, the rock is a phyllitic schist with needles of amphibole.

Mica-schist and garnet mica-schist.

In sheet 47H/16, in the Kadaval area, biotite-granet-schist predominates. The rock is mainly composed of biotite, garnet, felspar and quartz. As a result of the granite intrusions, the biotite-schist has been affected by pneumatolysis producing much tourmaline. The tourmaline shows light yellow to blue-green pleochroism and carries inclusions of biotite.

3. Metamorphism of the Kaladgi rocks.

The Kaladgi sedimentaries vary from sandstone to conglomerate, quartzite and shales, and the metamorphic derivatives of these are also of diverse nature. They consist of phyllites, mica-schist to garnet-mica-schist, biotite-granulites often with biotite and garnet and mica-schist injected with granite. The above rocks are found in close association with granite and pegmatite intrusions. They were mapped south of Kasal, north-west of Kudal, between Kudal and Akeri and in the Savantvadi granite intrusion. The nature of the various rocks imply varying degrees of the contact and dynamothermal metamorphism. Similar phenomena were also noticed by the writer in the Amherst district of Burma, where sedimentary rocks of the Taungnyo and Mergui series, consisting of sandstone, sandy shales and shales have been metamorphosed by the granite intrusions to quartzite, phyllite, phyllitic mica-schists and where intense granitisation has occurred, the product is a biotite-granulite.[1] The formation of garnet by thermal metamorphism of argillaceous sediments has been described by Harker.[2]

The variation from schist to granulite involves directed to uniform pressure in addition to temperature. Such areas, where granite intrusions occur, form deeply eroded regions of the earth's crust, where injection metamorphism and granitisation are prevalent. Changes might also occur, where only high pressure and great hydrostatic pressure are involved, which give the rocks even-grained, granulose and direction less structures[3] as is shown by the granulites.

[1] *Rec. Geol. Surv. Ind.*, 73, pt. 1, p. 16, (1938).
[2] A. Harker : *Metamorphism*, pp. 54-55, (1932).
[3] G. W. Tyrell : Principles of Petrology, pp. 313-315, (1926).

Such rocks are named by the Scandinavian geologists as "leptites", which are fine-grained granulose metamorphic rocks.

4. Correlation of the Arenaceous and Metamorphic groups Rocks.

Till the present study, the rocks of this area were treated as unmetamorphosed sediments and the underlying rocks as older metamorphics. The intrusive nature of the granite and its metamorphic effects on the sediments were not appreciated.

The metamorphosed suite of rocks is intimately associated with the acid intrusions which consist of coarse porphyritic granite and pegmatite veins. Part of the sediments has also undergone intense granitisation involving contact or plutonic and pneumatolytic metamorphism. The metamorphic rocks consist of mica-schist, garnet-mica-schist, biotite-granulite, often with garnet and hornblende and mica-schist injected with granite. There is ample evidence to prove that the metamorphics are the result of thermal metamorphism of the sediments.

Wilkinson has not attempted any correlation of the above mentioned rocks, but Foote has included them in his Lower Kaladgis. It has to be examined whether his assumption is correct or whether they belong to the Dharwars.

Such a vast stretch of country has not been continuously examined by any other geologist after Foote. He has examined the whole of the South Mahratta country, and traced the exposures of the Kaladgis from the eastern limits to its western limits and then passes on to deal with the Konkan exposures. According to him[1] the series of section extends to Gokak and along the Gatprabha valley to beyond Neseri (Naiseree) in the southern part of the Kolhapur State, from where it follows the line of great and small inliers, which connect or rather indicate, the continuity which subsisted before the trap covered up the surface of the country between the Kaladgi basin and the homologous rocks in the southern Konkan at the foot of the Phonda Ghat.

The distance of the Lora exposure at the foot of the Phonda Ghat to the type exposure near the western limits of the Kaladgi basin is about 60 miles, but in the intervening trap-covered area dissected by rivers like the Harankashi, the Vedganga and the

[1] *Loc. cit.*, p. 78.

Dudhganga, exposures of the Lower Kaladgis have been mapped by him. The distance between the last of these exposures and the Lora exposure is only 16 miles. The above evidence supports the idea of a large and extensive Kaladgi basin, in which sedimentation of diverse nature took place. The rocks formed have been separated partly due to folding and partly by the covering of the Deccan trap. Thus there is every probability that the arenaceous formations of Lora in south Ratnagiri are an extension of the Kaladgis.

Hematite-quartzites form very small exposures or isolated patches and also inliers in the arenaceous and metamorphic group of rocks. Beyond this there is no definite evidence to consider them as the Dharwars, and they have been called Archæan.

In the Ratnagiri district, the rock formations consist of an upper arenaceous group of quartzites with thin bands of shale and a lower metamorphic group derived from argillaceous sediments with a few arenaceous bands. These rocks have been supplemented by the granite intrusion with a certain amount of material. The Lower Kaladgis of the type area have a great similarity to the arenaceous group in south Konkan, but in the type area the argillaceous group has no representative below the base of the Kaladgis. This may be purely due to local difference in sedimentation. Correlation of the arenaceous group to the Lower Kaladgis is purely on lithological grounds, as both formations do not contain any fossils.

Do the arenaceous and metamorphic series belong to one series and does the latter form an older series and belong to the Dharwars? The rocks might be grouped into an older and newer series, but there is no definite evidence to consider them as Dharwars, since the metamorphics are always found with the granite intrusions. Thus positive evidence is lacking to consider them as Dharwars, but there is every possibility of its belonging to Kaladgis, since the Lora exposure has been traced to be an extension of the Kaladgis.

5. The granite intrusions, gneisses and contact rocks.

All the pre-trappean rocks of this area were mapped as one formation as gneisses by Foote,[1] but in his description the Kaladgi rocks have been separated from the others. He mentions two small inliers of granitoid gneiss, protruding among the sandstones and quartzites of the Kaladgi series at the foot of the Phonda Ghat.

[1] *Op. cit.*, pp. 37, 49-50.

The gneissic rocks, according to Wilkinson's description, consist of true gneisses, micaceous sandstone and some subordinate bands of granite and syenite-gneiss.

In the recent survey, granites and gneisses were found near a number of places and have been mapped as one formation. Most of the exposures have been found to be intrusive into the country rocks, producing varying degrees of contact metamorphism.

Kankauli area.—Biotite-hornblende-granite or gneiss forms the main intrusive rock of the area. A more highly banded gneiss occurs a little further east. The major joints of the granite run N. N. E.—S. S. W. (52/664, 52/668), specimens of the granite and gneiss from this area are usually composed of microcline, orthoclase, and a little plagioclase, quartz, brown hornblende, biotite and a little sphene. North of Janauli and west of Nagwa (16° 17′ : 73° 47′), in the river, some garnet-biotite-gneiss is present, but W. S. W. of Nagwa, coarse biotite-granite underlies the trap. On the low hills east of Janauli, the porphyritic crystals of felspar are oriented N. N. W.—S. S. E. in the granite.

Along the path from Kankauli to Harkul (16° 16′ : 73° 49′) biotite-granite was seen to be covered by trap. Weathered granite appears in all the road cuttings with thin bands of hornblende-schist. North of Kankauli also, between the first and second mile-stones in the road cutting, weathered granite and pegmatite are present.

On the road sections from Kankauli to Kasal, the granite veins are present in the shale, and at 26 m. 3 fur. trap covers the granite. East of Kasal-Malvan road, granite, biotite-granulite and vein quartz were found mixed up. A number of pegmatite intrusions are present and more granite near the road to Kudal. Near Kadaval (16° 8′ : 73° 49′, also pegmatite and granite-intrusions were noted in the biotite-schist.

Kudal to Akeri.—After the toll gate at Bitavna (15° 58′ : 73° 45′), granite appears and continues all along the road to Akeri. The granite forms huge tors along this road, and further down carries some inclusions of biotite-granulite, followed by more granite to Akeri. Along the path to Mangaon (15° 59′ : 73° 49′) more porphyritic granite (52/733, 734) appears, and the felspar phenocrysts are of orthoclase with inclusions of perthite. They are rectangular in shape, but the corners have sometimes been rounded. The ground-fabric is usually composed of microcline, a little plagioclase, quartz,

biotite, green and brown hornblende, iron-ore, apatite and sphene. Occasional bands of fine-grained granite are also present.

The porphyritic granite also appears west of Akeri at 68 m. 1 fur., to 68 m. 7 fur. and from 57 m. 5 fur. to 58 miles. Coarse biotite-granite is found with biotite-granulite inclusions.

Savantvadi area.—There is a large granite intrusion west of the town of Savantvadi, forming huge ridges running N. W.—S. E., and two roads cut across this ridge to Araonda (15° 43′ : 73° 42′) and Banda (15° 49′ : 73° 55′). The granite (52/767 and 769) is porphyritic with subordinate finer grained bands with intrusive relation to the country rocks, varying from biotite-garnet-granulite to biotite-schist.

On the path to Banda also coarse porphyritic granite is found and at the V bend an inclusion of granulite occurs. Below the hills the granite outcrops in the fields and also shows intrusive relation to the schists.

West and north-west of Savantvadi, the granite is porphyritic, shows horizontal jointing, and carries inclusions of biotite-granulite.

Vengurla. On the Bunder hill on the south side, granite boulders are very prominent and the granite continues for about a mile on the south side of the road. It also shows contact effects with the Kaladgi sediments. Here also the granite is porphyritic.

6. The Basic and Ultrabasic intrusions.

In the area examined in south Ratnagiri and Savantvadi State, a number of small exposures of basic and ultrabasic rocks were come across and they have been mapped separately. They comprise dolerite, olivine-dolerite or gabbro, picrite, and chromite-bearing serpentine. Foote includes them in the gneissic rocks and mentions talcose schists occurring near Akeri, W. N. W. of Sundarwari (Savantvadi), at Bamburda (eight miles north-east of Vengurla) and a few other places. Some reference is also made to the occurrence of actinolite-schist five miles N. N. E. of Kudal. Actinolite-schists were also noted at a number of places in the recent survey.

Dolerite.

The dolerite forms minor intrusions as dykes or small sills, common in the Kaladgis. On the Mangaon-Akeri path, a porphyritic dolerite was seen at 1 m. 3 fur. It forms a very dark and coarsely crystalline rock, composed of plagioclase felspar and pyroxene, which occur in equal quantity with the usual ophitic structure. This intrusion is in

granite. The augite forms large continuous patches with inclusions of felspar laths. Another exposure is north of Savantvadi branching of the road from the Vengurla-Belgaum road. At 55 m. 3 fur. on the above road, in a stream, the same type of dolerite is present.

Olivine-dolerite.

The Bav-Sonavda ridge is a curved ridge about 1½ miles north-west of Kudal. The rock is grey in colour, medium to coarse grained, and is mostly made up of plagioclase felspar, pyroxene and olivine. The felspar has been saussuritised, the pyroxene is partly altered, colourless and giving out iron-ore. It weathers in large boulders and is altered to laterite. Other exposures were found at 64 m., north of 54 m. 7 fur. and at 55 m. 4 fur. on the Vengurla-Belgaum road. In some of these rocks, the relation of the felspar and the pyroxene gives rise to pœcilitic structure. Specimen (52/733) is mostly composed of pyroxene and olivine in large grains showing reaction rims producing iron-ore and biotite. The felspar is subordinate and the pyroxene has some inclusions of olivine.

Picrite.

On the Danoli-Banda path, after the first col, there is an intrusion of picrite which runs for about half a mile, intruding into the sandstone and granulites of Kaladgi age. Specimen (52/763) from this exposure is a coarse-grained, holo-crystalline rock, mostly made up of crystals of pyroxene with a metalloidal lustre, and some olivine. Under the microscope, the pyroxene is colourless, with grains of olivine, slightly altered, and having marginal reaction rims giving out iron-ore. There is a little interstitial felspar with some inclusions of olivine.

Chromite-serpentine rocks.

These rocks are found near Kankauli and Vagda. As in other parts of the world they occur in the form of veins or lenses. The Kankauli lode is seen to cut across a dyke of quartz in an E. S. E. direction. The serpentine is also at times associated with actinolite and hornblende-schist. The Vagda exposure is composed of two ridges separated by a patch of cultivation. The serpentine is usually altered to laterite. The chromite occurs as an irregular lens or vein in the serpentine, with a sharp boundary, and which dips steeply southwards. These rocks are dealt with in greater detail in a separate paper.[1]

[1] *Rec. Geol. Surv. Ind.*, **74**, pp. 372-385, (1939).

7. The Basic Metamorphic rocks.

The rocks coming under this group consist of epidiorite, hornblende-schist, amphibolite and actinolite-schist. They form usually small veins, dykes or sill-like exposures in the country rocks of the area. They are perhaps due to different grades of metamorphism at different times.

Epidiorite was seen in the Kankauli area at two places in road cuttings one and two miles on the road to Harkul. (52/681), a specimen from one mile east of Kankauli has a doleritic texture, showing dark and light patches under the microscope, the felspars have been saussuritised, and the pyroxenes have gone into granular epidote, colourless hornblende, and much iron-ore. Some sericite is also present. (52/682), a specimen from two miles east of Kankauli breaks into slabs, and is mostly composed of hornblende and altered felspar, yielding granular epidote and quartz. Ophitic structure is also present.

Epidiorite.

Other exposures noted were a quarter of a mile west of the Kasal bridge, south of Suklavadi, in the field south of Varad, after 66 m. 5 fur. on the Vengurla-Belgaum road and west of the stream, at 59 m. 3 fur. on the same road, at 2 m. 3 fur. on the Savantvadi-Araonda road, and north of the pear shaped hill on Otavna (15° 43′ : 73° 55′) path. In all these rocks the felspars have been saussuritised, altered to sericite, epidote, albite, *etc.*, and the pyroxene altered to hornblende.

Amphibolite and hornblende-schists occur in a few places, as on the Halval-Vagda path. Here it cuts the pegmatite and is mostly made up of hornblende, felspar and quartz. Along with the chromite-serpentine rocks near Vagda (16° 14′ : 73° 45′), hornblende-schist and granulite occur. Three quarters of a mile east of Suklavadi, amphibolite was seen in the granite, forming a dark massive rock, composed mostly of hornblende. At 52 m. 2 fur. on the road to Amboli Ghat, it forms a dark and tough rock, composed of hornblende and felspar, as also at 50 m. 3 fur., where evidence of slickensided jointing is present.

Amphibolite and hornblende-schists.

Actinolite-schists (52/748) were also noted at 64 m. 1 fur. on the Vengurla-Belgaum road and at 1½ miles on the Banda path from Danoli (52/764). The former is a soft brownish-green rock with bundles and needles of actinolite, whereas the latter is a slaty

rock. The origin of the rocks is not clear, but the actinolite rock associated with serpentine-chromite rocks is a by-product of the serpentinisation.

8. The Deccan trap.

A large part of the Ratnagiri district is covered by the Deccan trap, but near the coast the trap has weathered into laterite. This feature continues from 17° to latitude 16° 30′. Near Karepatan (16° 33′ : 73° 37′) massive hills of trap have been alterred to laterite. In sheet 47H/11 and 15 in the western portion the trap stops at Shirgaon on the Devgad road. West of Shirgaon (16° 23′ : 73° 37′) to the coast it is laterite, which continues down to the coast. In 47H/15, the granite and gneiss are exposed in the valley of the Janauli and Gad rivers, and except for the Lora inlier of the Kaladgis, the rest of the area is covered by the Deccan trap. In sheet 47H/12, the trap is found on the foot of the hills west of the road to Kasal, while another exposure occurs six miles east of Malvan running north-west towards Mahan (16° 6′ : 73° 33′) and Bilwas (16° 7′ : 73° 34′), and also in the valley south of Salel (16° 4′ : 73° 37′). In sheet 47H/16, there is the continuation of the Ghats from sheet 47H/15 and its foot-hills, but on the western part, the valleys and foothills, granulite is exposed. But the higher portion of the ridges are covered by trap. In sheet 48E/9 and 13, the ghats still trend eastwards and are met on the road to Amboli Ghat at the 46th milestone which is east of this sheet.

The trap below the Ghats occurs as flat narrow ridges, exposed on the sides and in valleys and is often covered by laterite. In places the trap weathers into a dark reddish soil. In sections and cuttings, the columnar jointing is seen with spheroidal weathering. These features were seen on the Phonda Ghat road and the Amboli Ghat road, where the Sahyadris present steep ridges, with the horizontal flows of lava. It also weathers above the Ghats very readily into a dark soil, 'wacke' which with humus *etc.*, forms the black cotton soil.

Petrology.

The trap is usually a basalt, with a dark colour, and is a very tough rock, which is used for road metalling and for reinforced concrete. The partly weathered rocks have a dull brown or greyish green colour, but a perfectly black colour and lighter shades of it are also common. The

texture varies from a very fine-textured to a coarse-grained hemi-crystalline groundmass with phenocrysts of plagioclase felspar. When the groundmass is coarse-grained, the rock very much resembles a porphyritic dolerite, but there is always a little glass. The rocks are generally massive but on the road from Karepatan to Rajapur (16° 39′ : 73° 31′), the trap is vesicular and the cavities are filled by zeolites. Variation in the traps in the Ratnagiri district is in the amount of glass in the groundmass as also in the proportion of the felspar and pyroxene microlites. In a few instances some olivine was also noticed. Variation in texture is considerable, and palagonite was also found. Specimen (52/671), east of Halval, has more interstitial devitrified brown glass and iron-ore. Intersertal texture is present in most of them with minute wedges of glass filling the spaces between the crystals of the groundmass. Specimen (52/693) is a trap from near Kharepatan and has a very fine groundmass in which large phenocrysts of felspar and some pyroxene occur. A little olivine and palagonite are also present. Near Koloshi (16° 23′ : 73° 41′) (52/697), and north of Kasal (16° 9′ : 73° 44′) in the cutting near the bridge (52/710), small spherical masses of glass are present in the trap. Sir L. L. Fermor[1] has recorded shot-like spherules of glass in his Deccan trap flows of Linga. He considers the glass the same as the supposed chlorophæite so characteristic of flow 3 and that they are probably of a secondary zeolitic character, analogous in origin to palagonite glass.

In this area no intertrappean beds were found between the different flows of lava.

9. Laterite.

The coastal region of the Ratnagiri district, which has the alternate dry and wet season of the Malabar coast, is characterised by the laterite formation. In such regions, whatever be the country rocks, whether trap, granite, sedimentary and metamorphic rocks of the Kaladgis, the result of weathering is laterite.

Dr. C. S. Fox[2] who has made an extensive study of the aluminous laterite and bauxitic deposits of India, has described the lateritic rocks of the Ratnagiri district also.

[1] L. L. Fermor: *Rec. Geol. Surv. Ind.*, XLVI, pp. 19, 94-95, (1916).
[2] *Mem. Geol. Surv. Ind.*, XLIX, pp. 93, 95-96.

There is extensive quarrying of laterite everywhere for building stones. Stones measuring 3 ft. × 1 ft. × 1 ft. are very commonly used, but at times even larger slabs are removed from the quarries.

10. Alluvium.

In the area above described, alluvium forms very small patches in sheet 47H/11 and 15, and 47H/12 and 16 on the banks of the Gad and Karli rivers. Alluvial patches occur near Amrad on either banks of the Kasal river. The Karli river and its tributaries have a number of meanders with the alluvial patches always on the concave side of the curves. These patches form fertile lands, where paddy is the usual crop raised. Besides, along the coast, alluvial patches occur south of Vengurla and Malvan.

III.—GEOLOGICAL STRUCTURE OF THE ARA.

A rough hypothetical section from Phonda Ghat to Malvan has been included by Foote in his memoir[1] in which gneisses and metamorphic rocks underlie the whole area. At the Phonda Ghat, at the foot of the scarp the quartzite is underlain by the metamorphics, and then again followed by quartzite and trap. Then trap is shown for about eight miles, and followed by an inlier of quartzite in the Assiamat river. Trap and laterite above it continue till the Melgaon ravine. and west of it one outcrop of trap and two of laterite follow. The remaining portion of the section contains a patch of alluvium and then the Malvan quartzite.

The following is the explanation of the section after the recent survey (Pl. 31, fig. 1). At 46 m. 5 fur. on the road to Kolhapur the trap starts in towering ridges, and the quartzite is underlain by thin papery shales, which are followed by sandstone and quartzite. This is the Lora exposure section, which passes under laterite. After 2-3 miles of laterite the trap appears again, overlying the granite-gneisses, whose exposures are seen in the Janauli and Gad valleys, and then passes across laterite, covering the Kaladgis. Then it passes through laterite, alluvium and to the coastal sandstones and conglomerates of Malvan.

Another section is taken from Malvan towards Kupavda (16° 11′ : 73° 53′), see Pl. 31, fig. 2. At Malvan coast the sandstone and conglomerate form a narrow band and after a patch of alluvium

[1] *Op. cit.*, Pl. VIII, fig. 6.

forming low ground, laterite comes up suddenly with a rise in level. It forms a flat tableland, and after some distance the trap is also seen. Laterite is the next exposure, followed by Kaladgi sandstone dipping W. S. W. at a low angle, which east of an axis running N. N. W. to S. S. E., has been altered by contact metamorphism into biotite-garnet-granulites showing several varieties. Here the Kaladgis form an asymmetric anticline, capped by laterite and pitching under the trap and laterite in sheet 47 H/11. The southern end of the fold shows dips characteristic of a dome from Kasal to Katta; the granulites are interrupted by the granite and pegmatite intrusions, and on the east it is again followed by trap and laterite.

Kudal-Savantvadi area.—Proceeding south-east on to sheet 48 E/13, after the laterite plateau near Kudal, a more hilly area follows, dominated by granite intrusions which carry inclusions of granulites. Part of the granulites also pass into laterite, but, east of Danoli, laterite is rare, and friable sandstones belonging to the Kaladgis are met with. The dips are very much disturbed here and vary from south to S. S. E. East of Danoli dips are found towards west and east. This suggests that the fold previously described might be a continuation of the same fold of the Kaladgis, intruded, cut up and metamorphosed by another portion of the granite intrusion. But away from the granite and nearing the flows of the trap, unmetamorphosed and friable sandstone is seen at the 48th milestone on the Belgaum road. This area of the Kaladgis, along and near the road sections, has a number of basic intrusives and at times ultrabasic intrusions, metamorphosed into epidiorites and hornblende-schists. Unmetamorphosed members of the intrusives occur as picrites and dolerites.

IV.—ECONOMIC GEOLOGY.

Building stones.

Laterite is extensive, covering the trap, in the Konkan coast, Quarries are found throughout the area where stones up to 3 ft.× 1 ft.×1 ft. are usually extracted. It provides a very strong and popular building stone. In the trap area, the trap is also quarried in some places, and used by the P. W. D. for bridge work and culverts. For road metalling the trap and the biotite-granulite are in extensive use.

Chromite.

The occurrence of chromite deposits in Ratnagiri has been known for a long time, and mentioned in the *Bulletin of the Imperial Institute*, VIII, p. 401, (1910). Dr. P. K. Ghosh[1] also gives an account of these deposits.

The deposits near Kankauli (16° 16′ : 73° 45′) and Vagda (16° 14′ : 73° 45′) were examined by the writer.[2] The masses of chromite occur in serpentine intrusions in these localities in more or less horizontal tabular lodes. It has also been estimated that 50,000 tons of ore occur at Kankauli and about 17,000 tons at Vagda. It is likely that the serpentine intrusions extend downwards to a great depth and that there may be other lodes, which are not now exposed. The content of $Cr_2 0_3$ in these ores has been found to vary between 31 and 39·7 per cent. So these ores are of low grade.

Felspar.

Felspar occurs in several places in the Konkan, but only in one place it was found promising *i.e.* the large intrusion of almost pure potash felspar near Kadaval (16° 8′ : 73° 49′). This felspar has been already examined in the Geological Survey laboratory and has been found suitable for ceramic purposes. The occurrence is about two miles from the nearest cart road, and is about 27 miles from the port of Vengurla. The pegmatite is mostly of very coarse felspar, containing a very small amount of quartz and mica. Large quantities of felspar could be obtained from this boss of pegmatite. (See also *Rec. Geol. Surv. Ind.*, 74, p. 46, 1939.)

Glass sands.

In many places along the cart road in south Ratnagiri district and in Savantvadi State, sands suitable for glass-making are extracted from the Kaladgi sandstones.

Four samples of sand collected from different localities in this area, were examined in the Geological Survey laboratory with SiO_2 varying from 93·48 to 98·56 per cent., and Fe_20_3 content varying from 0·28 to 0·47 per cent.

[1] P. K. Ghosh, *Rec. Geol. Surv. Ind.*, LXXII, p. 30, (1934).
[2] *Rec. Geol. Surv. Ind.*, 74, pt. 1, pp. 33-34, (1939).

These sandstones when crushed are suitable for making bottle-glass, and can be easily transported by sea to Bombay. (See also *Rec. Geol. Surv. Ind.*, 74, pp. 46-47, 1939.)

Ilmenite.

Ilmenite was found in small quantity in the bay south of the port of Ratnagiri (17° 0′ : 73° 20°). The ilmenite has been deposited by the high tides during the monsoon months. It cannot compare in any way with the rich deposits of Travancore. (See *Rec. Geol. Surv. Ind.*, 74, p. 50, 1939.)

Iron-ore.

The occurrence of iron-ore at Redi (15° 45′ : 73° 44′) has been described under the Dharwars (see p. 8). A sample of the ore from the top of the hill was analysed in the Geological Survey laboratory and contained 91·06 per cent. of Fe_2O_3 equivalent to 64·1 per cent. of iron. Sir L. L. Fermor[1] examined this deposit in 1912, and predicted an export trade from this part of India. Redi is eight miles from the port of Vengurla.

Mica.

Mica has been found in a pegmatite near Kadaval (16° 8′ : 73° 49′). Some mica quarried from this place was brittle and of poor quality. In the larger pegmatite intrusions, books of mica were noticed measuring 2 to 3 inches perpendicular to the cleavage. Deeper parts of the pegmatite may perhaps contain mica of better quality.

V.—ACKNOWLEDGMENTS.

I have to acknowledge with thanks the kind help received from Mr. R. S. Hiremath, Collector of Ratnagiri, to Mr. A. B. Rege, Executive Engineer, Ratnagiri, and to Diwan Bahadur M. B. Rane, Diwan, Savantvadi State, while touring in Ratnagiri district and Savantvadi State, but for which my work could not have been finished in the time that was available.

[1] *Rec. Geol. Surv. Ind.*, XLIII, p. 18, (1913).

I wish to record also my deep sense of gratitude to Dr. A. M. Heron, Director, Geological Survey of India, for kindly going through this paper and for many valuable suggestions in the preparation of this paper.

VI.—EXPLANATION OF PLATES.

PLATE 26, FIG. 1.—View east of Phonda Ghat, showing foothills of Deccan trap —different flows are seen clearly.

FIG. 2.—Foothills of western ghats. Part of the ghat road is seen on the left.

PLATE 27, FIG. 1.—View of Malvan Fort in the sea. Foreground shows stacks of Kaladgi conglomerate.

FIG. 2.—Kaladgi sandstone showing a rolling dip, Malvan coast.

PLATE 28, FIG. 1.—False bedding in Kaladgi sandstone, Malvan.

FIG. 2.—False-bedded Kaladgi sandstone, Malvan.

PLATE 29, FIG. 1.—Garnet-mica-schist. West of Gad river, South of Kankauli. ×24.

FIG. 2.—Coarse biotite-granulite, path east of Kadaval. ×24.

FIG. 3.—Biotite-garnet-granulite, on Banda path from Wady. ×24.

FIG. 4.—Granite with inclusions-Vengurla-Belgaum road. ×24.

PLATE 30, FIG. 1.—Augite-picrite-Banda road after first col. ×24.

FIG 2.—Epidiorite, one mile east of Kankauli. ×24.

FIG. 3.—Deccan trap, near Koloshi. ×24.

PLATE 31, FIG. 1.—Section along a line from Malvan to Phonda.

FIG. 2.—Section along a line from Malvan to Kupavda.

PLATE 32, FIG. 1.—Geological Map of the Area.

ON SOME COPROLITES FROM THE MALERI BEDS OF INDIA. BY C. A. MATLEY, D.Sc., F.G.S. (With Plate 33.)

INTRODUCTION.

The collections of the Geological Survey of India contain sixteen coprolites from the Maleri formation, fifteen of which, numbered K42/417 to K42/431 were collected by T. W. H. Hughes in 1876, and one numbered K33/620 at a later date. All were obtained from the neighbourhood of Maleri. They are characterized by a spiral twist and have a strong resemblance to those from the Lower Lias of Lyme Regis, Dorset, England, described more than a century ago by William Buckland (1829, pp. 223-40), although they do not attain the size of his largest specimens.

OCCURRENCE.

The presence of coprolites in the Maleri Beds was first recorded in 1859 by Thomas Oldham who described some fish teeth and two coprolites collected from Maleri by Virapa, an assistant of Rev. S. Hislop, and gave the following account:—

"Pl. XV, figs. 11 and 12 represent two specimens of Coprolites, found along with these fish remains. They are enclosed in a thick concretionary layer of the ferruginous clay, in which they occur, which assumes the general form of the inclosed Coprolite. On breaking off this outer coating the true form, and spiral structure, of the Coprolite itself is seen within. They are composed of a white and powdery substance with some slight ferruginous stains. They still contain a large amount of phosphates, and, if occurring in any quantity, would doubtless prove a valuable manure". (1859, p. 308).

Blanford in 1878 stated that the fossils of Maleri were "picked up on the surface of the ground, and in no case have they been found *in situ*" (1878, p. 18) but does not mention coprolites. In 1881 W. King's account of the beds around Maleri appeared, in which he remarked that

"The commonest remains are coprolites which lie about the fields in large numbers, of all sizes and shapes, from the short cylindrical form with tapering ends and spiral foldings up to large flat rudely discoid coils" (1881, pp. 271-2).

For more than fifty years after King's work no fossils were collected from the Maleri area, but in 1935 Mr. N. K. N. Aiyengar (to whom the Author is indebted for the above references) was sent there to make a collection of reptilian remains. In a short report on the results of his work he made the following remarks on the occurrence of coprolites:

"Coprolites are abundant about a mile W. S. W. of Maleri. They are generally greenish yellow in colour varying in size from that of a walnut to a cocoanut. In shape some are flat and cake-like, some cylindrical, spiral, reniform or botryoidal. In cross section they present a central core surrounded by layers of iron-impregnated material. The nature of the material of these coprolites has not yet been examined" (1937, p. 104).

Mr. Aiyengar has also contributed the following account of their field-relations:—

"Maleri (Marweli of the map, sheet 56M/12, 19° 11′: 79° 36′) is a village about ten miles E. N. E. of Rechni Road railway station on the Balharshah-Kazipet section of H. E. H. Nizam's State Railway in Hyderabad. It may be mentioned here that Kota, which place is sometimes associated with Maleri in geological literature, as if the rocks of the two localities are of the same age, is at least 32 miles S. E. of Maleri, near Sironcha, on the left bank of the Pranhita, while Maleri is in Hyderabad. Kota beds are younger than the Maleri beds. About half a mile W. S. W. of Marweli (Maleri) coprolites are found in red clays in large numbers. The greater part of the area around Marweli is under cultivation. During annual ploughing the coprolites are brought up with the soil, *i.e.*, the red clays; consequently the coprolites are not found *in situ* but on the surface. In the same field I collected fish teeth (*Ceratodus*) and two large vertebræ which have been described by F. von Huene as a new species of reptile in a paper now in the press. Though most of the reptilian fossils were picked up from the red clays, in an uncultivated field about a mile south-west of Maleri I found large reptile bones weathered out on a calcareous sandstone. However, I did not notice any coprolite in the sandstone itself. As has been remarked by W. King, the coprolites are of varied shapes and sizes. As my search was confined to the neighbourhood of Marweli and the adjoining villages, a wider search on the rocks of the Maleri stage which extend from Sandgaom (19° 35′: 79° 42′) to Semnapali (18° 42′: 79° 54′) a distance of about 60 miles, may indicate the exact nature of the occurrence of the coprolites".

From the foregoing account it will be seen that the specimens under description are surface specimens. Only one reveals the nature of the surrounding matrix by the adherence of a small quantity of calcareous clay. Traces of a calcareous incrustation are found on a few of them; this is probably of Pleistocene or Recent date like the similar incrustation on the surface fossils of Cretaceous age found at Pijdura (Pisdura), Chanda District, Central Provinces.

DESCRIPTION.

Their shape is typically fusiform. The average length is 50 or 55 mm. the largest being 74 mm. as preserved but about 80 mm. when complete. The maximum width is usually about half the length, though the proportion varies. In transverse section they are somewhat oval, the maximum breadth being on the average about 12 per cent. greater than the maximum height. The initial end is broadly rounded and larger than the terminal end. They have a smooth and polished brown ferruginous coating; the smoothness represents a mucous surface and the coloration is probably a stain derived from the matrix which once enclosed them. Internally they are chalky and calcareous.

Structurally they consist of a thin lamina or ribbon of mineralised fæcal material wrapped spirally around itself in a closed coil of several overlapping turns which taper in the direction of the terminal end. In cases where either end of a coprolite has been broken or eroded the spiral is visible in transverse section (Pl. 33, fig. 2b). The thickness of the lamina varies from 1 to 3 mm. and is thickest where it is moulded upon a constriction in the underlying coil, as the material before extrusion was soft and plastic. The surface of the coprolites shows the course of the spiral band, though it is sometimes more or less concealed by an overlap of the outer layer. The largest specimen, 74 mm. long, (Pl. 33, fig. 8) is of rather exceptional shape in that it resembles a gastropod shell with a spire, a twisted columella and an outer lip; the presence of the 'lip' suggests that the winding of the spiral was in this case not completed and that, perhaps owing to the death of the animal, the excrement was not fully extruded.

COMPOSITION.

These coprolites are calcareous and phosphatic. One specimen analysed in the Geological Survey Laboratory at Calcutta showed 29·28 per cent. of Calcium Phosphate ($Ca_3P_2O_8$) and 25·63 per cent. of CaO. The remaining constituents were not determined. To the naked eye and under a pocket lens the material is a fine-grained paste without any noticeable inclusions, and in this respect it differs from the Lyme Regis coprolites which contain fish-scales, fragments of bone, etc., and evidently came from carnivorous feeders. It seems likely that the Maleri specimens were produced by vegetable

feeders or feeders on soft invertebrates. For the examination of a microscope section (Pl. 33, fig. 6c) of one of the specimens the author is indebted to Dr. J. D. H. Wiseman of the Department of Mineralogy, British Museum (Natural History) who reports that "the microscope helps very little to elucidate the mineralogical nature of this coprolite. A reddish fibrous substance occurs both in longitudinal layers and in isolated masses. Its colour intensity is variable and its properties are not sufficiently definite for identification." It may be stated that the reddish 'longitudinal layer' mentioned by Dr. Wiseman is the thin mineral layer that separates one turn of the spiral from the next.

Producer of the Coprolites.—It is clear from the mechanical structure of these coprolites that the producing animal possessed a spiral valve in its intestinal tract; it seems also to have been a plant-feeder or possibly a feeder on soft invertebrates. Further, as none of the coprolites shows any indications (such as the sun-cracks found on some of the Cretaceous coprolites of Pijdura) of having been dried in the open air, the animal was probably aquatic. Now, at the present day a spiral valve is known only in the Elasmobranch fishes, such as the skates, rays and sharks, the ganoid fishes and the Dipnoi or mud-fishes. It is not known in any modern amphibian or reptile. Buckland's spiral coprolites from Lyme Regis, which contained fish-scales, reptilian vertebræ and other bones, were attributed by him to Ichthyosaurs (1829) in spite of the evidence of a spiral valve, but Sir A. S. Woodward has since cast doubt on this ascription (1917) and thinks it much more probable that they were produced by the large sharks (*Hybodus* and *Acrodus*) which were as abundant as the marine reptiles. He also figured a spiral coprolite in place in the anus of the Devonian *Cladoselache*.

The vertebrate fauna of the Maleri Beds consists of several species of amphibia and reptilia and the Dipnoid fish *Ceratodus*. Of these only *Ceratodus* is definitely known to have had a spiral valve. It is also aquatic and a vegetable feeder, and these coprolites are therefore attributed to *Ceratodus* with much confidence.

Occurrences of spiral coprolites do not seem to be frequent or to have been often described; but in addition to those mentioned above J. H. Johnson (1934) has described from the Pennsylvanian of Colorado some which he thinks belong mainly to ganoid fishes of the genus *Palæoniscus*, and L. Neumayer (1904) others from the Permian of Texas, which he attributes to stegocephalian amphibians.

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EXPLANATION OF PLATE.

MALERI COPROLITES.

Plate 33, Figs. 1 to 8. Spirally-wound coprolites from Maleri. All natural size, except Fig. 6b (longitudinal section) x 2, and Fig. 6c (microscope section) x 2½. G. S. I. Nos. K42/417 to K42/424.

THE COPROLITES OF PIJDURA, CENTRAL PROVINCES. BY C. A. MATLEY, D.Sc., F.G.S. (With Plates 34, 35 and 36.)

INTRODUCTORY.

The small village of Pijdura, in the Chanda District of the Central Provinces, lies about 9½ miles north-north-east of Warora. It has previously appeared in geological literature as *Phisdura* (by Hislop) and *Pisdura* (by later writers), but on sheet 55P/3 of the new one-inch map it is shown as *Pijdura* and this revised spelling will be adopted in the present paper.

The Rev. S. Hislop first brought to notice the occurrence of coprolites at this locality (1860, p. 163; 1864, p. 281). They were found, together with vertebrate remains and other fossils, on the surface of cultivated land and were turned up by ploughing. Hughes, during his survey of the Wardha Valley coalfield found others (1877, p. 88). In 1920 I collected more, perhaps 30 to 40 (1921, p. 161; 1933, p. 5). In December 1932 Mr. A. M. N. Ghosh and I visited Hislop's area as part of the work of the Percy Sladen Trust Expedition and made an intensive search which yielded more than 600 coprolites besides abundant reptilian remains, mollusca, etc. The whole collection was sent to England, and from it I have selected about 350 coprolites for further examination, the results of which are given in the following pages.

I know of no other locality in India, or indeed in any other part of the world, which has yielded coprolites in such abundance and excellent preservation or in such variety or which contains specimens of so large a size.

MODE OF OCCURRENCE.

The coprolites were all found as surface specimens, as also were the associated fossils which consisted of reptilian bones and non-marine mollusca. Efforts were made by trenching and digging pits to find the bed or beds from which the fossils were derived but without success, and it was inferred that they had been transported some distance from their parent source. A fuller account of the stratigraphy will, however be given in a separate paper by Mr. Ghosh

and myself. Although the coprolites are usually complete, the bones are generally broken, many of the fractures being of a date subsequent to fossilation and their broken condition is certainly due in many cases to their removal from their original bed into the present sub-soil, further damage resulting from the effects of ploughing.

The coprolites, as also the accompanying bones, are almost always devoid of the original matrix except for such traces as occasionally adhere to the hollows and depressions of their surface. Such traces suggest that the fossils were chiefly derived from somewhat sandy beds, and one titanosaur centrum has patches of a coarse quartzose grit attached to it. One coprolite is still embedded in an impure limestone of Lameta type. The Pijdura fossils must, therefore have come from a group of sediments of varied composition, not from a single bed.

Many of the coprolites, especially the large ones, and many of the broken bones are coated more or less completely with a crystalline incrustation from 1 to 8 millimetres thick, consisting usually of calcite, sometimes of quartz or a mixture of the two minerals. This coating, as it overlaps the fractures and the remains of the original matrix, has evidently been formed in the present surroundings of the specimens and is of late date, Pleistocene or Recent; it may even be forming at the present day.

GEOLOGICAL AGE.

As they are derived fossils and their provenance has not been discovered the precise age of the coprolites becomes a matter of inference but it must be the same as that of the associated vertebrate remains (saurischia and chelonians). The Pijdura saurischia were described by von Huene and myself in 1933 (pp. 35-40); they are all titanosaurids and are assigned to the following species:—Cf. *Titanosaurus indicus*, *T. blanfordi*, Cf. *Antarctosaurus* sp., and Cf. *Laplatosaurus madagascariensis* (Deperet). Their age was thought by von Huene (*ibid.*, p. 71) to be probably lowest Senonian.

As regards the chelonians, Lydekker in 1890 (pp. 22-23) described a fragment from Pijdura as probably belonging to *Hydraspis leithi*, a Pleurodiran tortoise which occurs in Intertrappean beds at Bombay, and although he noted that there were some differences in its characters and its fragmentary nature made specific determination uncertain he used this specimen as an argument for the

occurrence of Intertrappean beds at Pijdura. The numerous specimens collected in 1932 have recently been examined by Dr. W. E. Swinton of the British Museum (Natural History) who finds that they are far too fragmentary for any satisfactory description but that some at least of these fragments may be referable to the species described by Lydekker. Other fragments certainly belong to a very much larger form of chelonian and of the genus *Testudo*.

Hislop also recorded some fish vertebræ from Pijdura, and this discovery was confirmed by the finding of a single vertebra of a fish by the Sladen Trust Expedition ; but fishes occur too rarely to be considered of importance as sources of the abundant Pijdura coprolites which may safely be considered to be of reptilian origin and of Upper Cretaceous, perhaps Lowest Senonian, age.

DESCRIPTION.

A preliminary examination suggests a classification of the coprolites into three, or perhaps four groups :—

(A) Very large forms, up to four inches in diameter. None of them shows ribbing. Their size shows that they must be of sauropodous origin. They gradate into forms of medium size, and a few cannot be satisfactorily separated from the small unribbed forms in Group C.

(B) Medium-sized with longitudinal ribbing. They pass down insensibly into

(Ba) Smaller size, with ribbing.

(C) Small size, without ribbing.

These groups have certain common characteristics. All are phosphatic, the percentage of calcium phosphate ($Ca_3P_2O_8$) varying usually from 36 to 45 *per cent.* They are mostly calcareous but a few are silicified. The fossilized fæcal material is very fine grained and no inclusions of bone-fragments or other carnivorous food-material have been detected by the naked eye or under a pocket-lens. A number of microscope slides have been very kindly examined mineralogically by Dr. J. D. H. Wiseman of the Department of Mineralogy, British Museum (Natural History). He reports that "the most interesting thing is the occurrence of a rather rare mineral, frequently associated with calcite in ovoid areas, which, so far as the optics are concerned would indicate pseudowavellite (5 CaO, 6 (Al, Fe)$_2$O$_3$, 4P$_2$O$_5$, 18 H$_2$O). Of course the occurrence

of this phosphatic mineral is not really surprising. Beyond this there is very little else to report. Unfortunately the ground mass, in most of the slides, is somewhat opaque, and in addition is very fine-grained. It is therefore impossible to come to any conclusion about it, unless one undertook a somewhat prolonged and detailed investigation."

In the following account the morphological terms used by Bertrand (1903) have to some extent been adopted. The initial end of a coprolite is that which first emerged from the body of the producing animal, and the terminal end that which was extruded last. The circumference is hardly ever circular but has a major and a minor axis; the major axis is regarded as the horizontal diameter and the minor as the vertical diameter. The greater dimension of the horizontal axis may be due, or partly due, to the spreading of the plastic mass after deposition, owing to gravity. We can therefore speak of the maximum breadth and maximum height of any coprolite.

Group A.

This group contains about 60 typical specimens, the largest of which weigh from 1½ to 3 lbs. and range up to 4 inches in diameter.

Form.—Their form is very variable, but they are always longer than wide, the length however rarely exceeding the maximum breadth. The longitudinal axis is moderately straight or gently curved. The initial end is larger than the terminal end towards which the hinder part of the body of the coprolite generally tapers, leaving the proximal part of the body with sub-parallel sides. The transverse section of the body of the coprolite is more or less elliptical, the height being less than the breadth. In the other groups of coprolites from Pijdura the initial end is typically well rounded and almost hemispherical, but in Group A, although the hemispherical shape is not uncommon, it is less characteristic and is often replaced by a flattish surface or a facet-like shallow concave depression. The terminal end may be bluntly rounded or taper to a blunt point, or sometimes terminate (like the initial ends mentioned above) in a facet-like flat face or concave depression. (Plate 34, figs. 6 and 7.) In such cases the fæcal material seems to have broken into segments during defecation, as may be seen with horse dung at the present day, leaving a facet at one or both ends of the segment.

Some of the specimens bear on their surface one, or perhaps two, constrictions which often do not extend completely round the circumference and usually take a more or less oblique direction (K42/434, K42/435a ; Plate 34, figs. 3 and 5) ; they may represent an arrested stage in the breaking up of the fæces into segments.

The smooth glossy surface (much like the inner surface of a lamellibranch shell or the outside of an egg shell) which these coprolites have represents no doubt the mucous coating of the excrement ; but it is hardly ever preserved completely in the larger specimens, for a decorticated area almost invariably occupies a longitudinal zone along part of the circumference, with a width of usually one-third of the perimeter. This damaged part lies always on the vertical axis and is therefore related to the position in which the fæces lay on the surface of the ground. The destruction of the coprolitic crust seems to be pæne-contemporaneous and may be attributed to the work of bacteria or to burrowing coprophagous organisms in the area where the dung was in contact with the substratum. This view is supported by the fact that the coprolitic material below the decorticated crust has lost the fine-grained homogeneous nature of the remainder of the coprolite and now has a decomposed appearance and shows curious structures some of which simulate a mass of small tubules. In an exceptional specimen (Plate 34, fig. 8) K42/438 the surface is covered by many semicylindrical grooves from 4 to 5 mm. wide (a few of which are filled in with sediment) and presents an appearance indicating that the dung had been attacked superficially, when fresh, by dung-eating larvæ, worms or perhaps beetles.

The smooth surface often bears wrinkles or creases due to muscular pressure, the wrinklings lying at various angles to the length, and these markings are occasionally seen to be overlapped by another layer of excrement which was added during its passage through the rectum or cloaca. Internally, the coprolite is a simple mass with none of the spiral structure produced by animals with an intestinal spiral valve, yet there are occasional external accretions to the main mass of the material, as mentioned above, and one specimen K42/469 has a hemispherical end covered by an outer layer 24 mm. thick. It is a sub-cylindrical coprolite with a maximum diameter of 77 mm. and with a length (not quite complete) of 138 mm.

Dimensions.—The two longest coprolites are 170 and 166 mm. long respectively, and the maximum breadth of two others is 105

mm. each. The following are the dimensions of some of the specimens :—

	Length.	Maximum Width.	Maximum Height.
	mm.	mm.	mm.
* K42/458	121	77	..
K42/469	138	77	..
K42/434	170	86	68
K42/435	166	68	67
K42/435a	133	65	58
K42/463	108	47	37

Composition.—The specimens are phosphatic. One example contained 44·84 *per cent.* of calcium phosphate ($Ca_3P_2O_8$) ; another one yielded on analysis only 16·51 *per cent.* but it has been silicified. Silicification is uncommon, the majority of the coprolites being highly calcareous with an appearance like hard chalk-marl. The compact material of which they are composed has small contraction cracks filled with calcite or silica ; sometimes the silica has the appearance of having replaced some organic substance. One specimen (K42/463) which probably belongs to this group contains numerous empty spherules, from 1 to 2 mm. in diameter, partly lined with quartz crystals ; they may represent gas bubbles in the fæcal matter. No definite food-fragments have been recognized in the fine-grained material, so that it is probable that the producing animals were plant-feeders. It may be mentioned that a very small amount (0·013 *per cent.*) of free carbon found on analysis may represent a minute quantity of carbonized plant-tissue.

Producers of Group A coprolites.—The great size of these coprolites makes it clear that they came from very large animals and they must therefore be assigned to the Titanosaurs whose remains are associated with them. From their weak dentition these reptiles are believed to have subsisted on soft vegetation such as water weeds, and the absence of inclusions in their coprolites is in accordance with this opinion.

Groups B and Ba.

The coprolites of Groups B and Ba are notable for the ribbing impressed on their surface. They are of smaller dimensions than the larger members of Group A but may attain a considerable size,

with a diameter up to 64 mm. They may be separated into Group B, those of medium size, and Group Ba, the smaller ones, but it is convenient to deal with both groups together as they agree in most of their characters. About 150 specimens (about 60 of B and 90 of Ba) have been examined. As the presence of ribbing on coprolites does not appear to have been recorded previously this feature will be dealt with in some detail.

Form.—Their form is variable. The larger ones, and some of the smaller, are often strongly arched with a curved axis. (Pl. 35, figs. 1, 3, 5; Plate 36, fig. 4.) The initial end is usually hemispherical and curved over towards the concave side; the terminal portion tends to be folded over the earlier extruded part and may be deflected as much as 180° in the horizontal direction from its initial direction, so that the material must have been quite soft when defecated. (Pl. 35, fig. 6; Pl. 36, fig. 1.) The terminal end varies in form and may be a circular concave facet, as in some of the examples of Group A. Some of the specimens are twisted spirally (mostly dextrally), but the spiral banding is superficial and was not produced by a spiral valve.

Circumstances of Deposition.—Unlike the coprolites of Group A, all or most of which appear to have been deposited in water, as would be expected from the habits of the amphibious sauropoda, the coprolites of Groups B and Ba seem to have been dropped on land as a number show sun-cracks and similar features of sub-ærial drying (Pl. 36, figs. 11, 12). Also, several specimens have a flattened face with seems to be a depositional facet formed by the spreading out of the soft fæcal mass when it fell to the ground on defecation; yet in these cases particles of the substratum are not found adhering to or penetrating the fæcal material, as would be expected.

Ribbing.—The surface is marked in part by a series of parallel incised lines or very narrow and shallow grooves which separate flat ribbon-like ribs of varying width but mostly from 3 to 9 mm. wide in the larger specimens and from 2 to 4 mm. in the smaller. The strength of the ornamentation varies considerably but, although not infrequently faint, is more commonly well marked and distinct. The ribs are not developed all over the coprolite; they are most prominent on the arched initial end and the convex border, are ordinarily absent or almost obsolete on the sides, and are absent on the concave side (except on two small specimens, K42/445 and

K42/447 (Pl. 36, figs. 2, 2a, 3). The normal direction of the stripes is longitudinal, but in a minority runs obliquely or spirally. There is so much variation in the details of the ribbing that no two coprolites agree in their minor features. Not only do the parallel bands or ribbons vary in number—often from 10 to over 20 may be counted but even the width of a ribbon may be seen to change as it is followed along its length; the incised lines between the ribbons may also change in depth and thickness or may die out, and sometimes a fresh groove may be interpolated in the middle of a ribbon. The ribbing is occasionally wavy or crumpled. Normally these markings are confined to the outer surface, yet there are several examples of the ribbing being overlapped by a layer of unribbed or very faintly ribbed material (K42/493, K42/494). One coprolite was discovered, by the accidental breaking of its initial end, to have good ribbing buried under a thickness of some 16 mm. of unribbed material. (K42/485). In a few cases the ribbing, running obliquely, is found only along part of the length and terminates suddenly, the remainder of the coprolite being devoid of ribs (K42/439; Pl. 35, fig. 2).

Some of the smaller examples (Group Ba) show a series of wrinkles radiating in a stellate manner from a focus at the centre of the initial end, these riblets continuing along the coprolite as parallel ridges. (Pl. 36, figs. 2, 2a, 3.) This feature suggests that the impression at the initial end was caused by pressure on the plastic material during the opening and distension of the anal or cloacal aperture under the action of the sphincter muscle.

Causes of the Ribbing.—These markings have clearly been impressed on the fæcal matter by contact with flexible structures in the interior of the intestinal canal during its passage and extrusion. I am not aware that similar markings are found in any modern reptilian excreta, so that it may be assumed that the intestines of some of the reptiles of the Cretaceous period possessed structures of the nature of rugæ or laminæ which differed materially from those of the present day. The details of this intestinal apparatus are however not clear, and it is possible that the rugæ were not permanent features but came into being as temporary ridges formed by compression and reduction of diameter of the mucous lining of the intestine during the passage of the fæces, the ridges disappearing later when the pressure was relieved. Varying circumstances would modify the number and thicknesses of

these ridges and cause corresponding variations in the ornamentation of the coprolite.

The prominence of the banding on the convex surface of the arched coprolites, together with its faintness or absence on the sides and concave surface implies that the rugæ, whether permanent or temporary, were not evenly distributed on the inner surface of the intestinal canal, but were especially strong on the dorsal side.

In order to obtain information as to the internal characters of the intestinal tract of modern reptiles I examined, at the suggestion of Prof. D. M. S. Watson, F.R.S., the preparations of modern reptilia exhibited in the Museum of the Royal College of Surgeons, London. Intestinal rugæ are not uncommon in modern reptiles but are most frequently present in the upper or small intestine where they would almost certainly be ineffective in marking the fæces. One preparation of a turtle (*Chelone*) shows that longitudinal rugæ are present in the lining of the great intestine, and these seem capable, in suitable circumstances, of producing markings not very unlike those found in the medium-sized coprolites from Pijdura. Another preparation shows that the intestine of *Chelone* can be so contracted as almost to obliterate the canal, the contraction causing the mucous lining to be corrugated with prominent rugæ. This type of structure supports the suggestion made above that some of the markings on the Pijdura coprolites may have been produced by temporary puckerings formed inside the intestine when under muscular compression.

I have found that a close imitation of the ribbon-like ribs separated by incised lines which is so characteristic of these coprolites can be made by folding several strips of paper longitudinally and laying the strips side by side with the folded edges parallel in such a way that each strip overlaps the next one. If an impression be then taken with plasticine the overlaps reproduce the ribbing and the impression of the folded edge of each strip forms an incised line. In nature the strips would be a parallel series of thin longitudinal laminæ of soft mucous membrane projecting from the inner wall of the intestine. A preparation of a structure of the type indicated is in the Museum of the Royal College of Surgeons, although it does not belong to the Reptilia. It is a portion of the intestine of a porpoise (*Phocæna communis*) in which the mucous membrane is produced into large longitudinal thin folds or laminæ; if fæcal matter in passing through this part of the gut crushed the laminæ

against the intestinal wall an overlapping of the laminæ would result, and any impressions left on the fæces would have a general resemblance to those of the Pijdura coprolites.

Dimensions.—The medium-sized (Group B) coprolites have a breadth of some 40 to 60 mm. with a length that rarely exceeds 90 mm. and averages perhaps 60 to 70 mm. but there are a few larger forms that bear some faint ribbing and reach up to 120 mm. in length with a maximum breadth of 70 mm. Those of the smaller forms (Group Ba) which are arched and approximate in shape to the larger arched forms have a diameter usually about 22 to 25 mm. while their length is about 45 mm. but in one example exceeds 70 mm. The other small ribbed forms which have not the arched shape are of much the same diameter, *viz.* about 22 to 25 mm. and 35 to 50 mm. long.

Composition.—The coprolites consist of a homogeneous buff or creamy paste in which are sometimes found delicate shrinkage cracks filled with calcite or occasionally with quartz. Chemically they are calcareous and phosphatic. Two specimens of Group B averaged 36·05 *per cent.* of Calcium Phosphate ($Ca_3P_2O_8$) and 19·47 *per cent* of lime (CaO), and two of Group Ba yielded 43·39 and 8·02 *per cent* of these substances.

Producing Animals of Group B.—The coprolites of Group B differ so markedly from those of Group A by their ribbing and by the arched form of many of them that they must have come from animals with a different type of intestinal apparatus and therefore are not titanosaurian. Now, the vertebrate remains found at Pijdura consist almost entirely of sauropoda (titanosaurs) and chelonians, and we seem to be left with only the chelonians as the source of Group B. In support of this view is the fact that the modern *Chelone* has longitudinal rugæ in its great intestine and also can contract its intestine so as to produce temporary corrugations (p. 543). The excreta were also deposited on land and their composition indicates that the animals were vegetable feeders. On the other hand the larger coprolites of this group seem to be of too great a diameter (up to 60 mm.) to have been extruded by the species of chelonians found at Pijdura, so far as can be judged from their very fragmentary remains, and it is possible that they may be the product of animals not at present represented in the Pijdura collections of vertebrate remains.

Producing Animals of Group Ba.—The coprolites of this group possess ribbing of much the same type as in Group B and a number are similarly arched. They are distinguishable from Group B by their smaller size, and may have come from young animals of the same species as produced Group B or from smaller species. They are probably chelonian.

Group C.

This group, of which about 130 specimens have been examined, consists of small unribbed forms. Their diameter is usually about 25 to 30 mm. but some larger specimens included in this group range up to 40 mm. in breadth.

Form.—They are mostly sub-cylindrical, sometimes sausage-shaped, but usually tapering gently towards the rounded terminal end where there is occasionally a small umbo. The longitudinal axis is straight. The surface as in the other groups is smooth and polished ; there may be some delicate muscular marks and wrinkles. In a few instances the surface is broken by bubble-like holes. The perimeter is often marked by one or two transverse constrictions which mark off the coprolite into two or three segments.

A few specimens show surface cracks of a type which indicate shrinkage and drying in the sun. (Pl. 36, fig. 13.)

Composition.—The material is fine-grained and homogeneous. Shrinkage cracks, filled with silica or calcite, due to consolidation during fossilisation are rare. As in the other groups they are phosphatic and calcareous. Two specimens contained an average percentage of 40·07 of Calcium phosphate ($Ca_3P_4O_8$) and 8·72 of lime (CaO).

Dimensions.—The longest example measures 68 mm. with a diameter about 34 mm. The smallest (a broken specimen) is only 12 mm. in width, another small one has a diameter of 16 mm. with a length of 39 mm.

Producing Animals of Group C.—The producers were no doubt land reptiles but of different kinds from those which deposited the ribbed coprolites. Their zoological position is uncertain ; they may have been chelonians or possibly small dinosaurs, as it is known that a large variety of Carnosauria, including Cœlurosauria, inhabited India in Upper Cretaceous time although their remains have not yet been found at Pijdura.

SUMMARY.

This paper records the results of the examination of about 350 coprolites selected from a collection of more than 600 found by the Percy Sladen Trust Expedition as surface specimens at Pijdura. They were associated with remains of sauropods (titanosaurs) and chelonians and are believed to be of Upper Cretaceous (perhaps Lowest Senonian) age. The largest specimens, some of which are four inches in diameter, are attributed to the titanosaurs found with them. The remainder are divisible into three groups, two of which are notable for their ribbed surface, a character indicating that the inside surface of the intestinal tract of the reptiles that produced them was longitudinally corrugated in its lower part; they may be of chelonian origin. The remaining group consists of small coprolites without ribbing and must have been produced by other reptiles.

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EXPLANATION OF PLATES.

PLATE 34.

[Pijdura Coprolites of Group A. All figures $\times \frac{1}{2}$.]

Figures 1 to 8.—Coprolites of Group A ($\times \frac{1}{2}$). Figs. 6a and 7a show ends of segmented specimens. In fig. 8 the surface has been channelled by coprophagous organisms.

PLATE 35.

[Pijdura Coprolites of Group B. All figures of natural size.]

Figures 1 to 6.—Ribbed coprolites of Group B ($\times 1$). Figs. 1, 3 and 5 show the typical arched form with ribbing dominant on arched surface. In fig. 2 the terminal (?) end is devoid of ribs, and in fig. 4a markedly ribbed core is overlapped by a very faintly ribbed layer. The ribbing of fig. 3 is exceptionally coarse. In fig. 6 the ribbing is deflected through two right angles.

PLATE 36.

[Pijdura Coprolites of Group Ba (Figs. 1-4) and C (figs. 5-10), and air-dried specimens (Figs. 11-13) all natural size.]

Figures 1 to 4.—Coprolites of Group Ba. Fig. 1 shows partial collapse and crumpling with deflexion of the ribs. Figs. 2, 2a, and 3 show riblets radiating from a focus at the initial end. Fig. 4, an arched form with irregular and somewhat crumpled ribbing.

Figures 5 to 10.—Coprolites of Group C.

Figures 11 to 13.—Air-dried coprolites.

A NEW FOSSIL FRESH-WATER TORTOISE FROM BURMA. BY W. E. SWINTON, Ph.D., F.R.S.E., *British Museum (Natural History)*. (With Text-figures 2.)

Some years ago an incomplete skull of a chelonian was collected by Dr. L. A. N. Iyer of the Geological Survey of India and I am indebted to Dr. G. E. Pilgrim, formerly of that Survey, for the opportunity of examining and describing the fossil.

The skull came from the Irrawaddy series (Pliocene) of the Shwebo District of Upper Burma. Although it lacks the anterior margin and a great deal of its hinder region, there is little difficulty in reconstructing the original outlines and appearance, and sufficient characters are observable to indicate without any doubt that the fossil is a form so far undescribed. I propose, therefore, to create a new genus and species for its reception, under the name of *Shweboemys pilgrimi*. The generic part of this name sufficiently indicates the origin and locality of the fossil while the trivial name is given in honour of the long and valued services of Dr. Pilgrim to Indian palæontology.

Shweboemys pilgrimi gen. et sp. nov.

Diagnosis. Skull large: pre-frontals not separated by nasals or frontals and entirely anterior to the hinder border of the orbits. Orbits circular. Maxillae stout and prominent on the palatal aspect. Palatines comparatively short and separated in the middle line. Internal nares between the palatines and pterygoids, connected by a groove with anterior palatal vacuity.

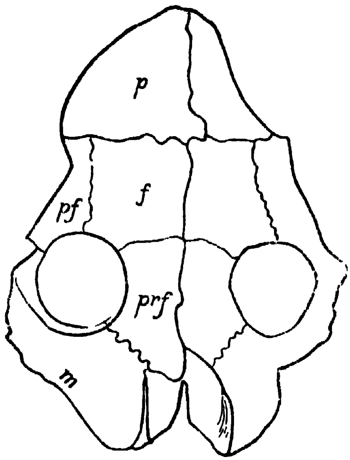
Horizon. Irrawaddy series (Pliocene).

Locality. One mile N. N. E. of Mauktet, Shwebo District, Upper Burma.

Holotype. Incomplete skull showing narial and orbital openings, maxillae, pre-frontals, frontals, post-frontals, anterior parts of parietals, and the palatines. G. S. I. Type No. 17255.

Description. The portion of the skull begins anteriorly with the broken inferior margin of the narial opening and extends behind to about an inch and a quarter behind the fronto-parietal suture. The total length of the preserved region is 4¼ inches. The distance between the front border of the nares and the hinder rim of the orbit

is exactly 2 inches, which indicates that the skull is that of a tortoise of considerable size, for the same narial-orbital measurement is



TEXT-FIGURE 1—Upper aspect of the skull of *Shweboemys pilgrimi*.
p=parietal; f=frontal; pf=post-frontal; prf=pre-frontal; m=maxilla. (× ½)

only 1¼ inches in a skull of *Podocnemis expansa* that is five inches long.

In the superior aspect there is close similarity between the new form, in so far as it is preserved, and the same region of *Podocnemis*, but since the postero-lateral borders are broken away there is no indication as to whether the temporal region was roofed as in that genus, or open as in *Sternothaerus*. The maxillary border is thick and comparatively high, ending in front on the narial opening and above in the lower rim of the orbit. Between these openings it is seen in sutural connexion with the pre-frontal.

The nasals must have been short and broad but are completely missing. The pre-frontals are a little longer than twice their breadth, and the right is a little longer than the left, precisely as in a specimen of *Podocnemis* that I have for comparison. The pre-frontals met the nasals a short distance in front of the orbits and articulate with the frontals in a suture, concave anteriorly, that cuts the median orbital margins at about half way between their front and hinder borders but which medially is on a line joining the hinder limits of

the orbits. It is noteworthy that the inter-orbital region is not concave but quite flat, and elevated.

The frontals are irregularly pentagonal, and have long sutures with one another in the middle line, and with the post-frontals externally. They have unequally long sutures with the parietals behind, and a short junction with the pre-frontals. The frontal forms the inner and posterior border of the orbit for a distance almost as long as the frontal-prefrontal suture.

Nothing can be said of the parietals except that their median suture is eccentric and at least ¼ inch to the left of the mid-line. Both parietals and post-frontals are fractured laterally leaving no indication as to their original extent, and the thickness of the bone at the fracture is similar to that of the roofed *Podocnemis* and the open forms of the Pelomedusidæ.

The openings in the facial region are not in any way remarkable. The narial opening is damaged but the orbital opening is normal and almost circular. The relative arrangement of the orbits and the narial opening is quite similar to that of *Podocnemis* but unlike that of *Stereogenys*.

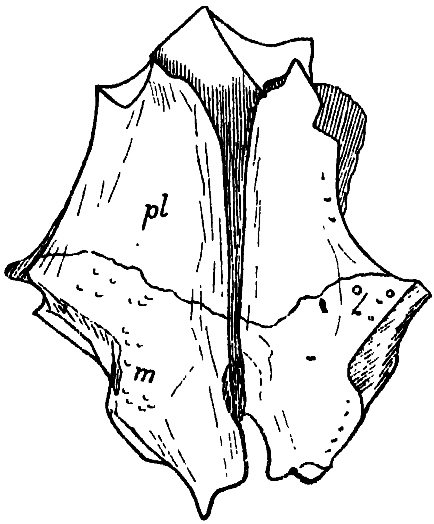
The upper surface of the skull, so far as it is preserved, is very closely like that of *Podocnemis*, apart from size and the inter-orbital condition already mentioned. With the upper surface of *Stereogenys* (Andrews 1901)[1], there are many differences. The breadth of the skull, its lack of height, the ovoid orbits and the comparative slenderness of the facial bones in the series of *Stereogenys* skulls from the Middle Eocene of the Fayum, Egypt, all serve to render the two skulls patently distinct.

The difference between the upper surface of the skulls of these two forms is of some importance for the palatal aspects of this new Burmese tortoise and of *Stereogenys* are remarkably alike and quite dissimilar to *Podocnemis*, or indeed any other chelonian.

The palate (fig. 2) shows the maxillæ, the palatines and a small portion of the pterygoids. Both the maxillæ and the palatines have pitted surfaces. The maxillæ take a larger share in the palatal aspect than might be expected, greater than in both *Stereogenys* and *Podocnemis*. Behind the maxillæ lie the comparatively short and rather hatchet-shaped palatines which are broken just where they form the ventral and anterior borders of the internal narial aperture. This opening was situated between the palatines

[1] Andrews, C. W., Geol. Mag., 1901, p. 442, fig. 4.

and the pterygoids. An interesting feature is that between the maxillæ and the palatines there is a well-developed and open cleft



TEXT-FIGURE 2—Palatal aspect of the skull of *Shweboemys pilgrimi*, pl=palatine ; m=maxilla. (× ½)

or channel running from a vacuity that existed between the premaxillæ and maxillæ to the inner narial opening. This cleft was no doubt covered by a membrane during life, but this arrangement, although so similar to the condition in *Stereogenys*, appears to be unknown, or at least undescribed, in all other chelonia. In side view the only noteworthy feature is the slightly concave wall which joins the lateral edges of the post-frontal and parietal, and descends to the maxillo-palatine border. This wall is about the same curvature, vertically and horizontally, as in *Podocnemis*, but not so rounded as in *Stereogenys*.

The broken edge of bone on the upper border is 2/10th of an inch thick but this appears to be no indication as to whether any lateral roofing existed or not. There is no evidence of any foramen in the lateral parietal surface as here preserved.

In brief, the interest of the specimen is that in superior and lateral aspect there is little to distinguish it from the genus *Podocnemis*, while in palatal view it has much similarity to *Stereogenys*. There is no doubt that it differs from both genera and is a new form belonging to the family Pelomedusidæ.

FOSSILS FROM THE KOJAK SHALES, BALUCHISTAN. BY F. E. EAMES, B.Sc., A.R.C.S., F.G.S., *Messrs. The Burmah Oil Co., Ltd.*

In the course of their investigations into the stratigraphical relationships of the Kojak shales Mr. E. R. Gee of the Geological Survey of India, and Dr. A. Allison and Mr. A. N. Thomas of the Burmah Oil Co., Ltd., discovered nine fossil beds in these strata.[1] The localities of these fossil beds are :—

Localities 1-3 . . .	Near Nawe Sakai, Kila Abdullah, Khojak; 34 J/10: 30° 41′ 35″ : 66° 39′ 30″.
Locality 4 . . .	Pishin district; south side of trig. station 7,600, north side of Surkhab valley; altitude 7,250 ft.; 34 N/2; 30° 35′ 32″ : 67° 10′ 31″.
Locality 5 . . .	Pishin district; south side of trig. station 7,600 north side of Surkhab valley; altitude 7,250 ft.; 34 N/2; 30° 35′ 38″ : 67° 10′ 30″.
Localities 6-7 . . .	Pishin district; Nigandi Kuz, north side of Surkhab valley; 34 N/2; 30° 37′ 6″ : 67° 13′ 40″.
Locality 8 . . .	Pishin district; Nigandi Kuz, north side of Surkhab valley; 34 N/2; 30° 37′ 10″ : 67° 13′ 6″.
Locality 9 . . .	Pishin district; Nigandi Kuz, north side of Surkhab valley; 34 N/2; 30° 37′ 24″ : 67° 12′ 50″.

The following fossils have been identified in the material collected from these beds :—

Locality 1 . .	*Cycloclypeus* sp.
	? *Lenticulina* sp.
	Lepidocyclina (Eulepidina) dilatata (Michelotti).
Locality 2 . .	*Lepidocyclina (Eulepidina) dilatata* (Michelotti).
Locality 3 . .	*Lepidocyclina (Eulepidina) dilatata* (Michelotti).
Locality 4 . .	*Camerina fichteli* (Michelotti).
	Camerina intermedia (d'Archiac).
Locality 5 . .	*Lepidocyclina (Eulepidina)* sp. *A*.
	Hydnophora sp. *A*.
Locality 6 . .	*Camerina intermedia* (d'Archiac).
	Camerina sp. *A*.
	Camerina cf. *fichteli* (Michelotti).
	Camerina cf. sp. *A*.

[1] *See Rec. Geol. Surv. Ind.*, 74, Pt. 1, pp. 25-26, (1939).

	Camerina sp.
	Globigerina sp.
	Rotalia sp.
	Triloculina sp.
	Indeterminate microforaminifera.
	Lithothamnion sp.
Locality 7 . .	*Camerina fichteli* (Michelotti).
	Camerina intermedia (d'Archiac).
	Camerina sp. *B*.
	Heterostegina sp. *A*.
	Camerina cf. *intermedia* (d'Archiac).
	Globigerina sp.
	Operculina sp.
	Rotalia sp.
	Triloculina sp.
	Coral.
	? *Lithothamnion* sp.
Locality 8 . .	*Camerina fichteli* (Michelotti).
	Lepidocyclina sp.
Locality 9 . .	*Camerina* sp. *B*.
	Lepidocyclina sp. *B*.
	Camerina cf. *fichteli* (Michelotti).
	Camerina sp.
	? *Lenticulina* sp.
	Lepidocyclina sp.
	"*Miliola*" sp.
	? *Operculina* sp.

Lepidocyclina (*Eulepidina*) *dilatata* (Michelotti) has been found in India only in the Nari series; the sub-genus has not yet been recorded from below the Oligocene. In India, *Camerina intermedia* (d'Archiac) and its megalospheric form *Camerina fichteli* (Michelotti) are very common in the Lower Nari; recently, however, the latter species has been found in the Khirthar shales in association with many characteristic Khirthar species, *e.g.*, *Fasciolites ellipticus* Sowerby, but is of rare occurrence. *Camerina* sp. A has been found in the Burmah Oil Company's collections from the Lower Nari.

The fossil beds in Localities 1, 2, 3 and 5 are thus not older than Nari; those in Localities 4, 7 and 9 are not younger than Nari,

and it seems that they are more likely to be of Nari age than Khirthar; that in Locality 6 seems to be of Lower Nari age.

It seems probable that all the fossil beds are of Nari (Upper Oligocene) age, a conclusion which is in agreement with E. Vredenburg's opinion as to the age of the Kojak shales.

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THE INDOBRAHM OR THE SIWALIK RIVER. BY B. PRASHAD, D.Sc., F.R.S.E., F.R.A.S.B., F.N.I., F.L.S., F.Z.S., M.B.O.U., *Director, Zoological Survey of India, Calcutta.*

In connection with my studies on the Zoogeography of India I looked up the literature dealing with the Palæogeography of Northern India and the changes that have occurred in this area since the late Tertiary times, for, as the late Sir Archibald Geikie (1894, p. 192) rightly remarked, "In order to understand the geography of any region as it now is, we must learn how it has been gradually built up. No country came into existence just as it is. If we would discover how its topography has originated, we must study the results of long-continued geological observation." No new ideas are put forward in this short paper, but the following notes are the results of a bibliographic research in connection with the explanations that have been advanced by geologists and zoologists for the extensive changes in the main drainage lines of Northern India and which, according to various authors, have resulted in a complete reversal of the directions of flow of the Ganges and the Brahmaputra.

The Indo-Gangetic alluvial plain is formed by extensive valleys lying immediately to the south of the Himalayan ranges and is watered at the present day by the three river systems, the Brahmaputra to the east, the Ganges in the middle and the Indus in the extreme west. These three river systems, according to Annandale (1922, p. 144), "at any rate in their present course, are approximately contemporaneous in origin and cannot have arisen earlier than the middle part of the Tertiary epoch". Geologists have tried from time to time to prove, on geological and faunistic grounds, that the Indus and Brahmaputra had a common origin and at one time formed parts of the same mighty river; a similar connection between the Ganges and the Brahmaputra has also been postulated.

As a result of a study of the Punjab Oil-belt Sir Edwin Pascoe (1919, p. 138) advanced a series of hypotheses in regard to the early history of the Indus, the Brahmaputra and the Ganges. His

second hypothesis, with which alone we are concerned here, was enunciated as follows:

"That this gulf gave place to a great river (for which he proposed the name *Indobrahm*), the headwaters of which consisted of the Brahmaputra flowing through Assam. This river flowed westwards and north-westwards along the foot of the Himalaya as far as the North-West Punjab, where it turned southwards along a line not very different from that of the modern Indus, and emptied itself into the Arabian Sea. In other words, the Assam Brahmaputra was once the head-waters of the Indus."

He remarked that this hypothesis seems to be adumbrated by R. D. Oldham in 1893 (p. 444) as follows:

"the great bulk of the Himalayan drainage once found its way to the Sea by a single delta, instead of two, and this must have been at the head of the Arabian Sea, or of the Bay of Bengal. The indications of the sea having extended up the Indus Valley within the recent period, and the absence of any similar indications in the delta of the Ganges, make it probable that the former was the original outlet of the drainage, and that the formation of the gap between the Rajmahal and Garo hills, and the Gangetic Delta, is geologically of recent date."

Pilgrim (1919) almost simultaneously and independently from a study of the Siwalik Boulder Conglomerates came to the conclusion that these beds:

"are capable of explanation only on the supposition that they were laid down in a rock basin formed in the valley of a large river (for which he proposed the name Siwalik River) by upheaval........... In Eocene times when sea covered the whole of the Western Himalayas such a river must have risen on a watershed connecting the Rajmahal hills to those of Shillong and the upper valley of the Brahmaputra. and continuing into China. A tributary of this river, draining the Eastern Himalayas, may at a later period have become the main river ot Northern India."

This Siwalik River was supposed to have flowed in a westward and north-westward direction, and its approximate position during the Pleistocene was believed to coincide "with the outcrop of the Upper Siwaliks (*vide* Pl. II, fig. 2)". As a result of intensification of the upheaving forces of the Himalayas during the last stage of the Siwalik Period the direction of flow of the Great Siwalik River was entirely reversed, and drainages of the Western and Eastern Himalayas "separated by the hilly country of the Aravallis and Rajputana" were respectively effected into the Arabian Sea by the Indus System and into the Bay of Bengal by the Ganges and its tributaries.

R. D. Oldham (1893, p. 428) had remarked that:

"There is no ridge of high ground between the Ganges and Indus drainage and a very trifling change in the surface might at any time turn the affluents of

one river into the other. It is reasonable to infer that such changes have taken place in past times, and that the occurrence of closely allied species of *Platanista* (a freshwater dolphin peculiar to the Indus, Ganges, and Brahmaputra) in the two rivers, and of many other animals common to both streams, may thus be explained."

This and the footnote with regard to Murray's ingenious hypothesis to account for this phenomenon are a *verbatim* reprint of Blanford's account in Medlicott and Blanford's first edition of *A Manual of the Geology of India* (1879, p. 392). Murray (1866, p. 214) to explain the occurrence of allied species of *Platanista* Cuvier in the Ganges and Indus river systems had suggested that the plain of upper India formed a part of the more extensive Arabian Sea in the earlier times, but with the rise of the coast in Sind and Cutch this area was cut off from the Arabian Sea and gradually converted into a brackish and later a freshwater lake, in which marine dolphins became gradually transformed into the freshwater Platanistidae. The occurrence of allied or identical species of Platanistidae in the Indus and Ganges systems was explained by Murray as being due to the connections of this lake with the two river systems at different times. As Blanford (1879), however, had remarked, this hypothesis was not "proposed as a geological theory, but merely as illustrative of the possible mode of origin of allied species." Oldham (1893, p. 443) in reference to Murray's explanation remarked:

"There is some direct evidence in favour of the more recent origin of the Gangetic outlet in the presence of closely allied species of dolphins in the Ganges and Indus rivers, of a very different generic type from the cetacean inhabiting the Irawadi. These two species must be descended from a common ancestor which acquired a freshwater habitat, and the differentiation of the Indus and Gangetic species have arisen from a subsequent separation of the drainage areas."

In this connection it is pertinent to refer to an unfortunate omission on the part of both Blanford and Oldham to Anderson's memoir (1878) in which he had definitely shown that the freshwater Gangetic Porpoise described as *Platanista gangetica* by Lebeck (1801, p. 280) was identical with *P. indi* described by Blyth (1859, p. 493) as a distinct species from the Indus. Anderson from a detailed comparison of the structure of the two species was able to establish that the Indus species is identical with the earlier known Gangetic form and that it also occurs in the Brahmaputra, but not in the Mahanadi. Further evidence in support was supplied by the studies of Annandale on the aquatic Chelonia, according to which the forms found

in the Indus are identical with those of the Ganges, but the presence of the same species of porpoise in the Ganges and the Indus was considered by Pascoe (1919, pp. 154, 155) to be a very strong argument in favour of an organic connection between the Ganges and the Indus.

Annandale (1912, p. 261) from a study of the aquatic Chelonia of the Mahanadi River came to the conclusion that the Mahanadi races of several forms, particularly of *Trionyx gangeticus* Cuvier, are distinct from those found in the Indus and Ganges systems. Smith (1931, pp. 167, 168), however, has since shown that the Mahanadi race of *T. gangeticus* is not different from the typical form which occurs in the Indus and Ganges river systems.

Annandale (1922, p. 145) in his masterly analysis of the Marine Element in the Fauna of the Ganges concluded that for the faunistic similarities it was "not necessary to postulate that the Indus and the Ganges were ever joined together as rivers. At the beginning of the Tertiary epoch the territory which is now Peninsular India, one of the oldest of existing land-masses, was separated from the rest of Asia by a comparatively broad strait, in which conditions were completely marine. With the elevation of the Himalayas the channel became narrower, but probably was not completely obliterated. The streams that flowed down the southern slopes of the new mountain range must have brought with them much alluvium, the accumulation of which at its base would tend to fill in the channel. That this process was uniform all across the continent is improbable, and we may picture the existence of great lagoons, the interrelations of which were constantly changing, while their bed is now completely buried beneath the alluvial deposits of more recent rivers. Such a history would have given ample opportunities for the migrations of the fauna now common to the Indus and the Ganges".

Oldham (1894, p. 170) in his paper entitled *Evolution of the Indian Geography* summed up the changes in the drainage of the Indo-Gangetic plain as follows:

"Another result of these earth-movements was the formation of a depression parallel with the ranges, and separating them from the peninsula of India, which has been filled up by the Indo-Gangetic alluvium. At first the drainage of this depression had but one outlet, where the Indus now reaches the sea, and in this great river, formed by the whole of the drainage of the Himalayas, a certain species of dolphin established itself, and gradually acquired the habit of living and pur-

suing its prey in freshwater. At a later period a depression was formed between the Rajmahal and Assam hills, by which a gradually increasing portion of the drainage escaped, and the single river broke up into two separate drainage systems, one finding its way to the sea by the Indus, the other by the delta of the Ganges and Brahmaputra. The date of this separation is geologically recent, and the diversion of the drainage from the Indian Ocean to the Bay of Bengal must have been a gradual process, whose final stage, the permanent diversion of the Jumna into the Ganges, may even have taken place within the historic period (*vide* Oldham, 1886). Before this the waters of the Jumna must have flowed westwards, then it may have wandered and flowed alternately into the Ganges and Indus, or that dry river channel which can still be traced through the desert of the Western Rajputana. In its latest stage it probably, like the Casiquiari in South America at the present day, divided its waters between the eastern and the western drainage; but now no further change can take place, for the river has cut its channel deep below the general level of the plain, and must perforce remain a tributary of the Ganges."

Kobelt (1899, p. 91), a zoogeographer and conchologist, basing his views apparently on Oldham (1893, p. 428), in a paper on the zoogeography of India remarked that the streams flowing from the Himalayas have often changed their courses, and apparently in the earlier times flowed much nearer along the foot of the hills. The Indus and the Ganges are not separated by any well marked watershed, and it is not impossible that the upper tributaries of the Ganges in the earlier times used to flow into the Indus.

" Indus und Ganges werden durch keine ausgesprochene Wasserscheide getrannt und es ist nicht unmöglich, dass die obersten Zuflusse des Ganges in früheren Zeiten dem Indus zugeströmt sind. "

Fox in his handbook on the *Physical Geography for Indian Students* (1938, p. 319) has admirably summed up the situation as follows :

" Except for certain hypothetical cases of *river capture*, such as the probable deflection of the Tsanpo by the Brahmaputra into India and a great change in the watershed between India and Tibet as a consequence, there are not many established instances of the alteration of watersheds in India. It has been suggested that at the close of the Tertiary era (Siwalik times) a great river having its source in Upper Assam flowed along the base of the Himalaya to the Punjab and so round by the Indus valley to the Arabian Sea of that period. Young rivers cutting back from the Bay of Bengal, presumably the Bhagirathi and Brahmaputra, have deflected the older Siwalik river, or Indo-Brahm, southwards and produced the modern Ganges and Brahmaputra rivers. However interesting this explanation may be of the birth of the Ganges its disagreement with many facts can be easily proved, such as the presence of an estuary in Upper Assam close to the supposed source of the Siwalik river. But there seems to be little doubt that the present

Jumna river, from about Karnal, north of Delhi, and the existing Ghaggar, from near Nahan east of Ambala, both flowed westwards to combine about Suratgarh in north Bikaner and continued as the Hakra through Bahawalpur to join the Indus. The dry bed of the Hakra or Lower Ghaggar is still recognisable and is shown on most maps of North Rajputana or the Southern Punjab."

Wadia in the revised edition of his *Geology of India* (1939, pp. 40, 41) sums up the late changes in the drainage system of North India as follows:

"Many and great have been the changes in the chief drainage lines of North India since late Tertiary times—changes in fact which have produced a complete reversal of the directions of flow of the chief rivers of North India. The formation of the long thin belt of Siwalik deposits along the foot of the Himalayas from Assam, through Kumaon and the Punjab to Sind, widening steadily in its westward extension, is now ascribed to the flood-plain deposits of a great north-west-flowing river lying south of and parallel with the Himalayan chain from Assam to the furthest north-west corner of the Punjab, and then flowing southwards to meet the gradually receding Miocene sea of Sind and Punjab. This river has been named the 'Siwalik River' by Pilgrim and the 'Indobrahm' by Pascoe, from the combined discharge of the Brahmaputra, Ganges and Indus which it carried at one time. This old river is believed to be the successor of the narrow strip of the sea—the remnant of the Himalayan sea left after the main uplift of those mountains—as the latter gradually withdrew, through the encroachment of the delta of the replacing river, from Naini Tal, Solon, Muzaffarabad and Attock to Sind. The Nummulitic limestone deposits of these localities testify to the extent and boundary of the Eocene gulf. The final extinction of this gulf, which once stretched from Assam to Sind, left behind it a wide river-basin in which were laid down the thick series of Murree and Siwalik deposits during the interval between the Middle Miocene and the end of Pliocene. Post-Siwalik earth-movements in N. W. Punjab brought about a dismemberment of this river-system, which hitherto had flowed from the head-waters in Assam, through the whole breadth of India, to Potwar and thence to the receding head of the Sind Gulf, into three subsidiary systems: (1) The Present Indus from north-west Hazara; (2) the five Punjab tributary rivers of the Indus; (3) the rivers belonging to the Ganges system which finally took a south-easterly course."

From the above it is apparent that the first definite suggestion for the occurrence of a single westwardly flowing river for the drainage of both the Eastern and Western Himalayas into the Arabian Sea was put forward by R. D. Oldham in 1894. In 1919 Sir Edwin Pascoe and Dr. G. Pilgrim almost simultaneously and independently suggested such a river in the Tertiary times based on studies of the Punjab Oil-belt and the Siwalik Boulder Conglomerates respectively. The evidence from the faunistic point of view for such a river, however, as Annandale (1922) pointed out, does not lend enough support to this view.

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PLATE 24.—*Palmoxylon kamalam* Rode.

FIG. 1.—*Palmoxylon kamalam* Rode. (× ½).

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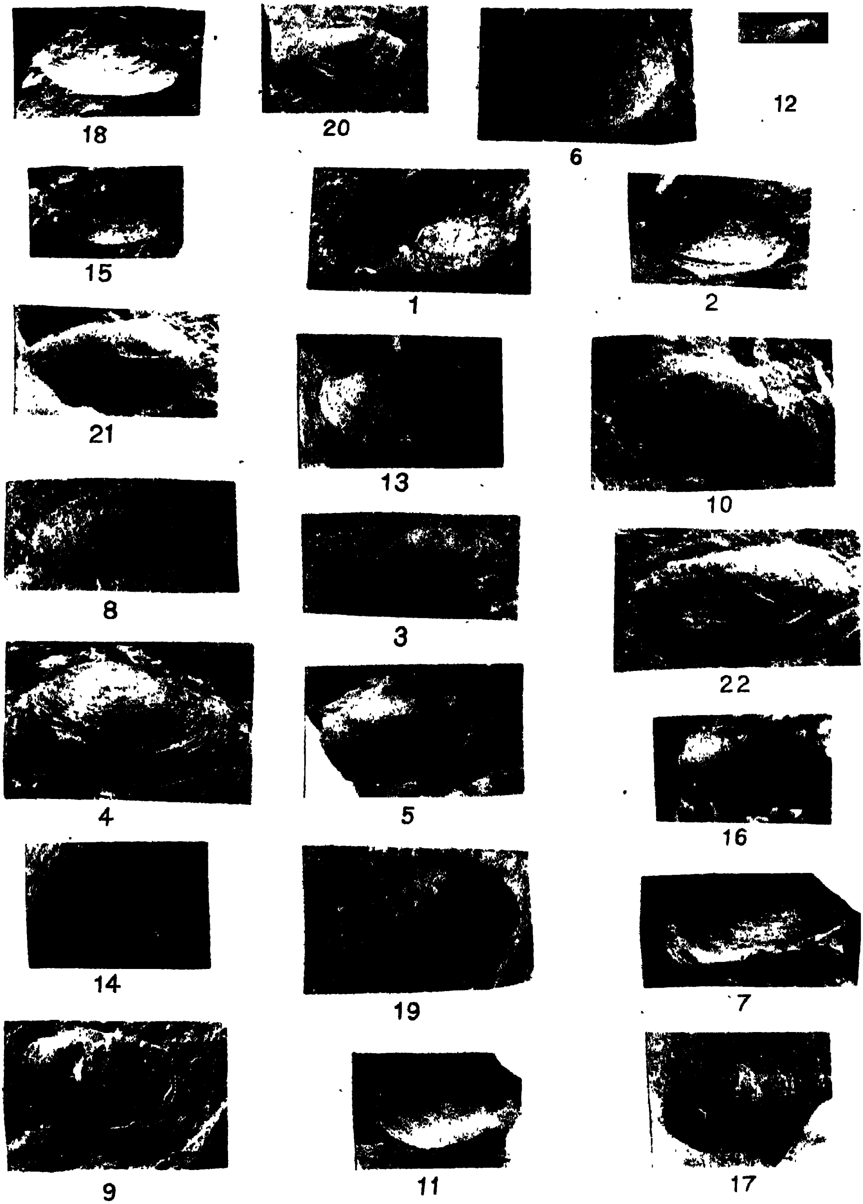
FIG. 10.—A small portion of the ground tissue as seen in transverse section showing the aggregation of crushed cells subjected to compression which form thick zig-zag lines to demarcate the irregular compartments in the ground tissue. (× 125).

MGIPC—M—VIII-1-14—12-3-41—725.



FOSSILS FROM 'SPECKLED SANDSTONE', SALT RANGE.

S. N. Das, Photos. *G. S. I., Calcutta.*

FIG. 1. ($\times \frac{1}{2}$).

FIG. 3. ($\times$ 1).

FIG. 4. ($\times$ 1).

FIG. 2. ($\times \frac{1}{3}$).

FIG. 5. ($\times$ 1).

PALMOXYLON KAMALAM RODE.

V. B. Shukla, Photos. *G. S. I., Calcutta.*

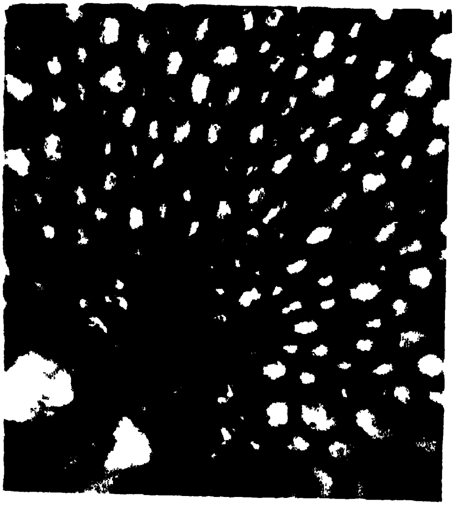


FIG. 6. (× 300).

FIG. 10. (× 125).

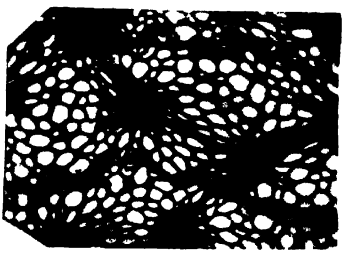


FIG. 9. (× 20).

FIG. 8. (× 300).

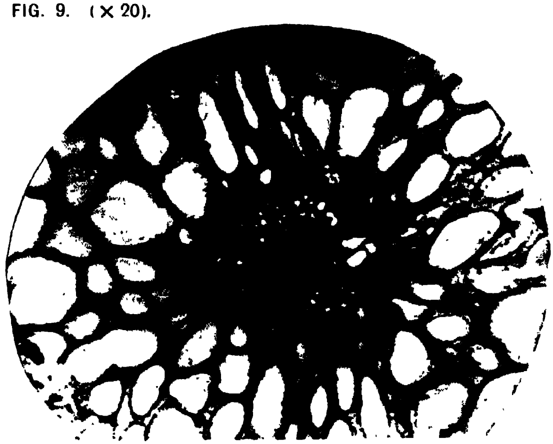


FIG. 7. (× 125).

PALMOXYLON KAMALAM RODE.

V. B. Shukla, Photos.

G. S. I., Calcutta.

FIG. 1. VIEW E. OF PHONDA GHAT, SHOWING FOOT HILLS OF DECCAN TRAP. THE DIFFERENT FLOWS ARE SEEN CLEARLY.

L. A. N. Iyer, Photos. *G. S. I. Calcutta*

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L. A. N. Iyer, Photos. *G. S. I. Calcutta.*

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FIG. 1 FALSE BEDDING IN KALADGI SANDSTONES, MALVAN.

L. A N. Iyer, Photos G S. I Calcutta.

FIG. 2. FALSE-BEDDED KALADGI SANDSTONE, MALVAN

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FIG. 1. GARNET-MICA-SCHIST, W. OF GAD RIVER S. OF KANKAULI. (× 24).

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L. A. N. Iyer & S. N. Das, Photomicros

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G. S. I., Calcutta.

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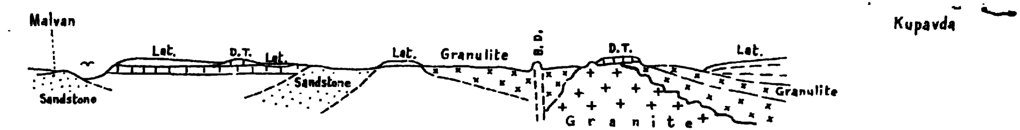
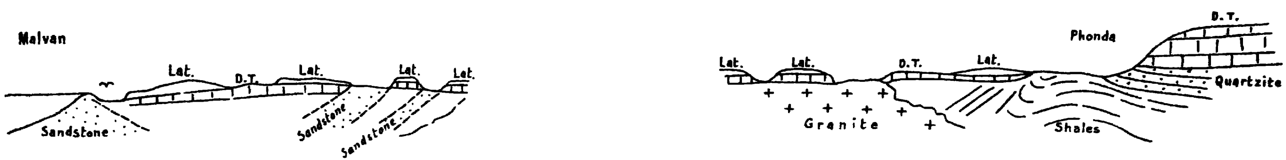
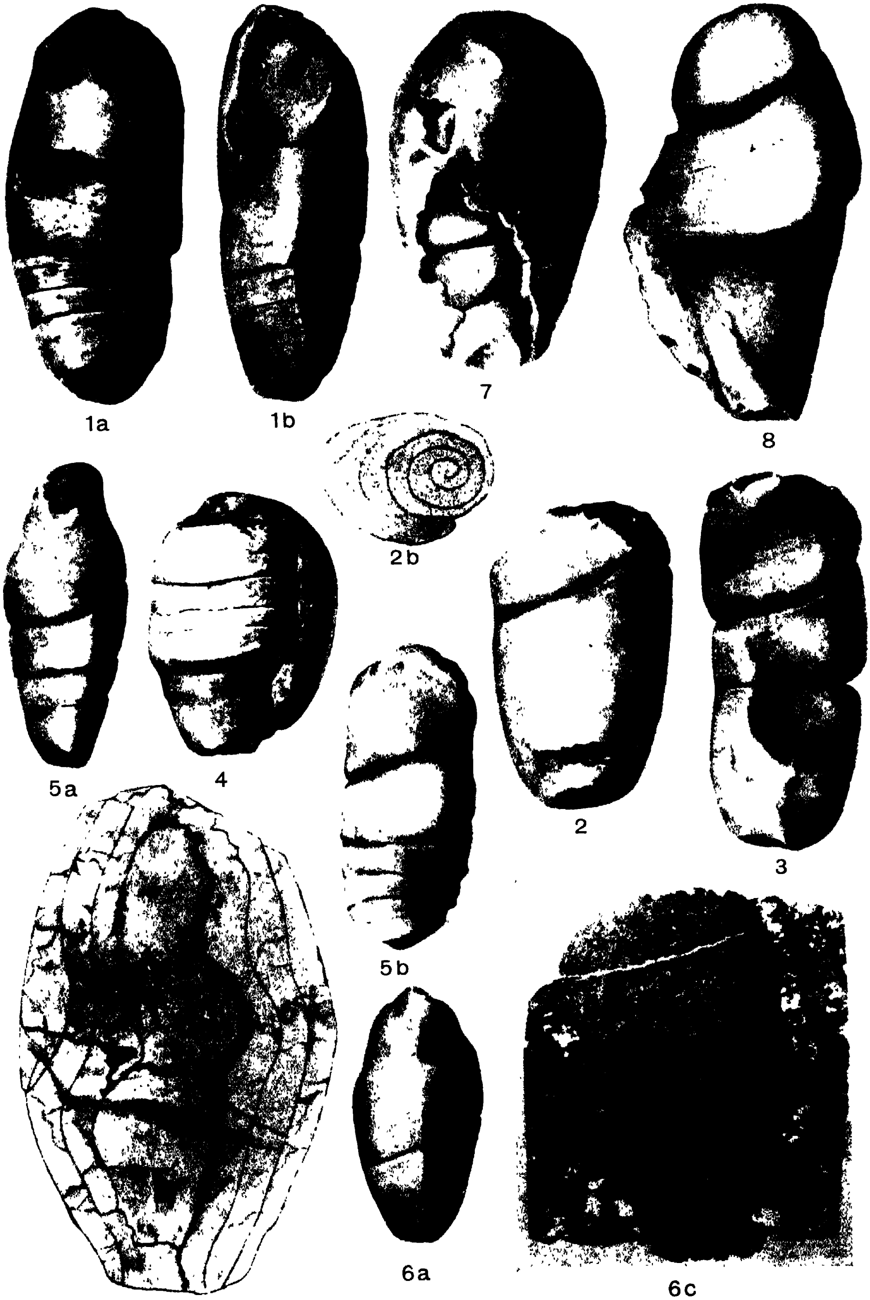


2. Section along a line from Malvan towards Kupavda.



1. Section along a line from Malvan to Phonda.

Horizontal Scale, 1 inch = 5 miles.



COPROLITES FROM MALERI BEDS.

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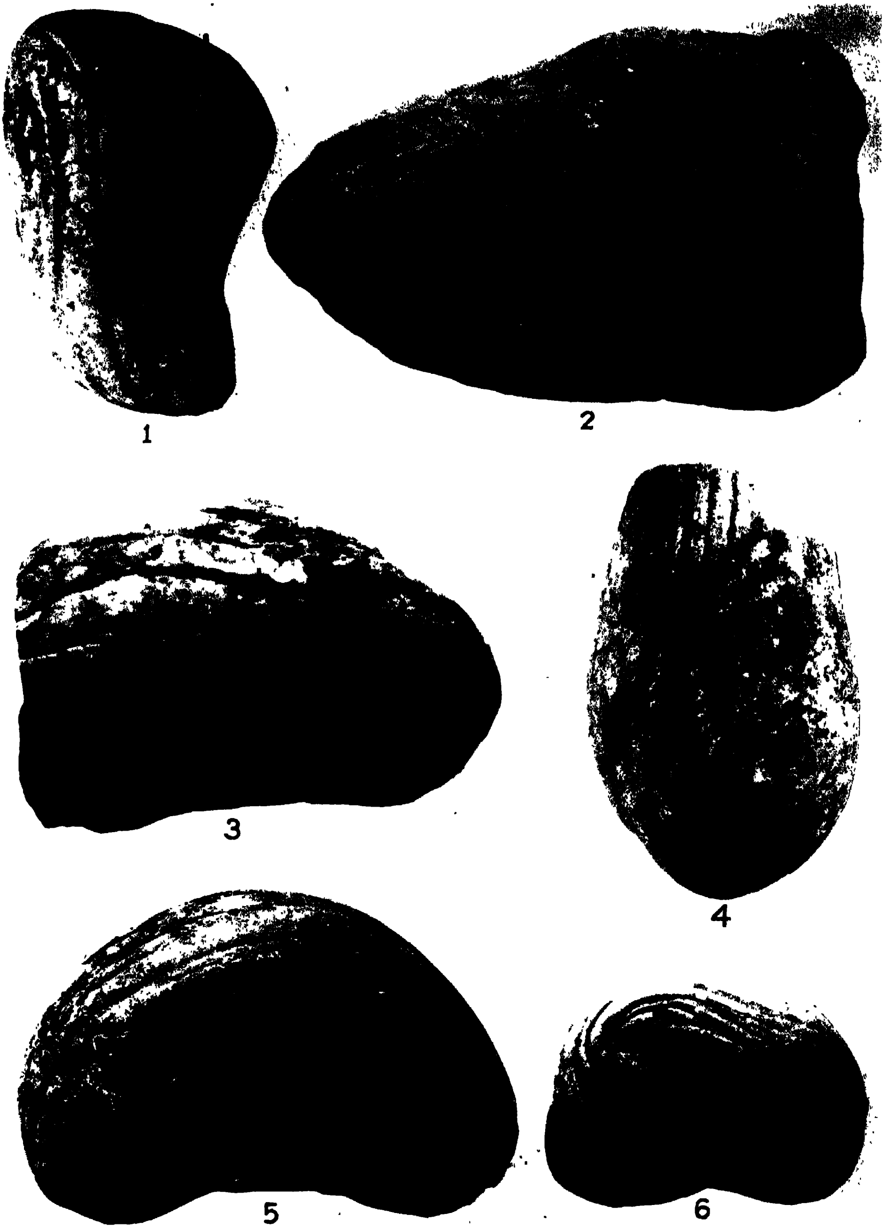

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